GUIDE BOOK No. 9

# Transcontinental Excursion C 2

## Toronto to Victoria and return via Canadian Pacific, Grand Trunk Pacific and National Transcontinental Railways

*ISSUED BY THE GEOLOGICAL SURVEY*

3

OTTAWA
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# SUDBURY, ONTARIO, TO DUNMORE, ALBERTA.*

BY

W. H. COLLINS AND CHARLES CAMSELL.

From Sudbury westward to Murray mine the main line of the Canadian Pacific railway ascends among hills of granite and highly folded Huronian greywacke, arkose, quartzite and greenstone to the southern margin of the great boat-shaped intrusive body with which the nickel deposits of this district are associated. The southern rim of the intrusive is crossed between Murray mine and Azilda, the gossan and dark basic rocks of the outer edge passing insensibly into flesh-coloured micropegmatite as the inner edge just west of Azilda is approached. From Azilda almost to Onaping the railway is within the elliptical area enclosed by the rim of the nickel eruptive and for practically all of this distance it traverses a flat plain of stratified clay formed in a part of old Lake Algonquin. The sandstone member of the Upper Huronian series which occupies the basin of the nickel eruptive and underlies this lacustrine clay, outcrops in low, dome-shaped hills at Chelmsford and Larchwood. The hilly rim of the nickel eruptive is again crossed, from the acid to the basic edge, in the neighbourhood of Onaping and Windy lake and a great monotonous region of Laurentian granite-gneisses and Keewatin schists is entered, which continues for the next 450 miles (725 km.).

The granites and gneisses of this region are characterized on the whole by an abundance of lime-soda feldspars and range in composition from granite to granodiorite, less frequently to syenite or diorite. But between Peninsula and Middleton the railway crosses a plutonic mass of nepheline and other alkali-syenites, 15 miles (24 km.) in diameter. This is the only known area of alkaline rocks in the region between Sudbury and Port Arthur. It is described in greater detail in the guide book of Excursion C 1.

As seen along the railway the alkali syenite mass appears to possess a basic margin. Its eastern edge consists of dark red augite syenite. This gives places more or less gradationally to pale feldspathic syenites in the centre of the area near Coldwell, and from Coldwell to Middleton the

*For a more detailed descriptiõn of this portion of the Excursion see Guide Book No. 8, Part I.

same transition occurs in reverse order, the western margin consisting of dark red syenites like those near Peninsula. A great variety of rock types, ranging from nepheline syenite to olivine gabbro, is present but they are all evidently the result of one act of plutonic intrusion. The latest investigators regard the order of consolidation to have been in general from the most basic to the most acid type, followed by a final intrusion of dykes of camptonite and allied materials.

The mass is intrusive into Keewatin schists and Laurentian granite-gneiss.

Lake Superior is in sight at intervals from Peninsula to Nipigon

The Keewatin and Laurentian rocks that reappear at Middleton continue to Gurney where they become overlain by flat-lying Keweenawan sediments and diabase sills intrusive into these sediments. The first of these formations seen is a bright red sandy dolomite, which contains disseminated patches of gypsum, and other evidences of arid climatic conditions at the time of its deposition.

The intrusive diabase sills appear near Kama, giving a first impression of the precipitous mesa-like topography which they produce in greatest prefection near Fort William. The shore deposits of old Lake Algonquin are also exposed in cuttings near Nipigon.

Between Nipigon and Port Arthur, Animikie (Upper Huronian) and Lower Huronian rocks also appear. These as well as the other Pre-Cambrian series are particularly well exposed near Loon. In this locality which is described more fully in the guide-book of Excursion C1, the Keewatin volcanic rocks and Lower Huronian conglomerate, greywacke and greenstone have been intruded by Laurentian granitic batholiths and so folded and altered to schists that a separation of the two groups is almost impossible. The flat-lying and little metamorphosed Animikie sediments lie unconformably upon a greatly eroded surface of these older rocks. They consist, from top to bottom, of (1) black slate, (2) upper iron formation, (3) slate, (4) thin-bedded, impure limestone, (5) iron formation, and (6) quartz conglomerate. The lower iron formation, is, perhaps, of greatest interest for it exhibits a variety of stages in the development of iron ore from the lean iron formation. Keweenawan conglomerate, sandstone and impure limestone, all deposited in shallow water, lie un-

conformably upon the Animikie. These formations as well as the older ones, are intruded by dykes and sills of diabase.

The relations of these sills to the Animikie sediments is particularly well shown in Current River park, Port Arthur, where a flood, caused by the bursting of a dam, has swept the rock floor quite free of soil. This rock floor consists largely of the upper surface of a diabase sill upon which vestiges of the original covering of black slate still adhere. Slight contact metamorphic changes are observable in the slate, and there are local anorthosite segregations a few feet in diameter in the diabase due to aggregation of labradorite phenocrysts.

The Port Arthur district contains a number of silver mines, including the famous Silver Islet mine, which bear considerable resemblance to those at Cobalt. The deposits are fissure veins carrying native silver, native bismuth, and various arsenides, antimonides, sulph-arsenides, etc., of silver, cobalt and nickel. Like the Cobalt deposits also, they are closely associated with the intrusive diabase sills. The Port Arthur district is described at greater length in the guide-book of Excursion C1.

Between Fort William and Summit, a distance of 18 miles (29·0 km.) the railway traverses a flat delta plain but the characteristic flat-topped hills of this locality appear in the distance to the south. These, of which mount McKay is perhaps the best example, consist of flat-lying easily eroded Animikie sediments protectively capped by remnants of the intrusive diabase sills.

These formations thin out and finally disappear near Summit beyond which lies another great region of Laurention gneisses and Keewatin schists. This region, extending for 340 miles (547 km.) to Darwin, is more heavily drift covered than that along Lake Superior but is not essentially different from it structurally or lithologically. The glaciated topography is more subdued and rocky lakes are more numerous. Excellent views of Eagle lake are obtained at Vermilion and of Lake of the Woods just west of Kenora. Gold is mined on Eagle lake, Lake of the Woods and at numerous other points in the Keewatin south of the railway. The stratified clay near Dryden, which was probably deposited in a small glacial lake, supports a scattered farming community and is used for brickmaking at Dryden.

Near Darwin the Pre-Cambrian shield disappears at a very low angle under the alluvial plain representing the bed of glacial Lake Agassiz. Between this station and Winnipeg the old lake bed gradually changes from a slightly rolling, heavily forested country to level, treeless prairie. The Ordovician limestone of the interior plains regions, which laps over the Pre-Cambrian shield from the west, is hidden beneath the Lake Agassiz silts and clays except near Tyndall and Garson where quarries may be seen at some distance from the railway.

Winnipeg is the gateway to the Great Plains of Western Canada. It is situated in the basin of glacial Lake Agassiz, an extinct lake which drained southward to the Mississippi, and deposited a thick sediment of silt and clay on a bed rock of Paleozoic limestone. The bed of Lake Agassiz has an elevation of 800 feet (243 m.) above sea level and forms the first prairie level of the Great Plains.

The western border of Lake Agassiz is the Manitoba escarpment which crosses the Canadian Pacific railway about Austin, where the surface of the plain rises to the second prairie level. This line of escarpment is coincident with the eastern edge of a wide band of Cretaceous which rests on the Paleozoic rocks and extends westward to the Rocky mountains.

The second prairie level has an average elevation of about 1600 feet above the sea and continues westward on the line of railway for about 280 miles (450 km.) to a point a short distance beyond Moosejaw. It is underlain by flat-lying Cretaceous rocks which, however, are so uniformly covered with a thick soil that outcrops of them are rarely exposed except in the river valleys.

The Missouri Coteau a few miles west of Moosejaw rises somewhat abruptly for about 500 feet (152 m.) from the second prairie level and forms the eastern boundary to the third prairie level which then stretches without any notable breaks to the foot of the Rocky mountains. To the south of the railway line between Moosejaw and Dunmore irregular flat-topped hills rise 1000 feet (304 m.) or more above the general level of the plain as remnants of a once higher plain since largely destroyed by erosion. These hills are built of undisturbed shales, sandstones and conglomerates of Oligocene age deposited after the period of crustal disturbance in which the Rocky mountains were elevated.

At Dunmore the route of Excursion C 2 leaves the main line of the Canadian Pacific railway to follow the branch line through the Crowsnest coal fields and the metal mining districts of Southern British Columbia, joining the main line again at Revelstoke, British Columbia.

## DUNMORE TO BURMIS.

BY

D. B. DOWLING.

### INTRODUCTION.

The country traversed by the Canadian Pacific railway between Dunmore and Burmis is underlain by Cretaceous and possibly Tertiary rocks (St. Mary River series). The following are the geological formations in descending order:

St. Mary River series.
Pierre shales.
Belly River series.

From Dunmore to a point a little east of Lethbridge the country is underlain by the Belly River formation arched in the form of a flat anticline, the centre of which is probably near Bow island. The formation consists of shales and sandstones of brackish water deposition referred to Upper Cretaceous.

Succeeding the Belly River are the marine Pierre shales, the latest purely marine sediments of the plains. The beds have a slight dip to the west, which increases southwards, and are faulted with small displacements showing that the effect of the Laramide revolution extended as far east as Lethbridge.

The St. Mary River sandstone marks the top of the Cretaceous and may possibly be Tertiary. The attitude is that of a synclinal fold, the eastern limb being approximately at the crossing of the railway over the Old Man river, while the western limb lies between Pincher and Cowley at the crossing of the south fork of the Old Man river. Westwards from this point to Lundbreck successively lower beds are crossed, and at Lundbreck the rocks, which are of fresh and brackish water origin, are supposed to be the

equivalent of the Belly River series. The exposures occur along the banks of the Crowsnest river.

Westwards the dips vary greatly in direction and degree and show evidence of folding in the strata. Near Burmis a great fault occurs with a down throw to the east which brings the beds of the Lower Cretaceous in contact with the higher members. Coal seams occur in the Belly Rivers series.

## ANNOTATED GUIDE.

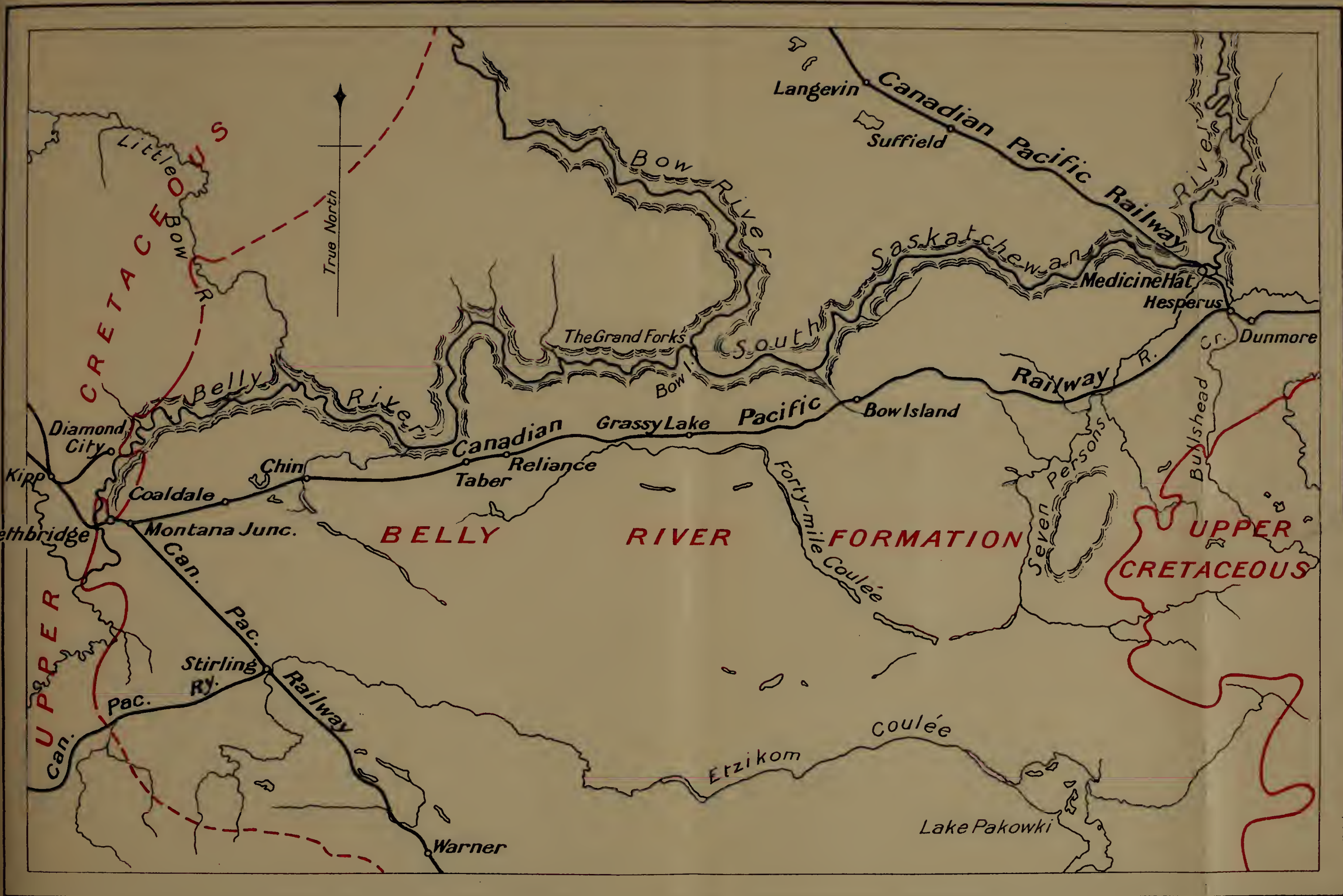
Miles and Kilometres.

0 m.
0 km. **Dunmore.**—Altitude 2,398 ft. (729 m.). Boring operations for gas at Dunmore Junction were successful in reaching a supply at about 1200 feet. The upper part of the section passed through in boring, consisted of shales and sandstones with lignitic seams, while the lower part consisted essentially of shales.

17·4 m.
28 km. **Seven Persons.**—Altitude 2,482 ft. (754 m.) To the south may be seen the extreme western end of the Cypress hills formed here of a lov plateau called the Bull's Head. The slopes show some of the light coloured clay characteristic of the top of the Belly River formation. The top of the plateau is probably overlain by Pierre shale.

41 m.
65·9 km. **Bow Island.**—Altitude 2,608 ft. (793 m.). Between the railway and the South Saskatchewan river several borings for natural gas have been made through the Belly River series to Dakota sandstone near the base of the Cretaceous. A plentiful supply was found at a depth of 2,000 feet (609 m.). The gas is conveyed to Lethbridge and Calgary through a pipe line the total length of which is 180 miles (288 km.).

76·5 m.
123 km. **Taber**—The Canada West Coal Company operates a small mine situated to the west of the town. The seam, which is horizontal and reached by a shaft about 100 feet (30·4 m.) deep, is at about the same horizon in the Bel River series as the one at Redcliff near Med cine Hat. It has a thickness of 4 feet (1·2 m with a parting of 3 inches (7·5 cm.) near th top. The coal is sub-bituminous, approachin




Geological Survey, Canada

Route map between Medicine Hat and Lethbridge

Miles
5 0 10 20 30 40
Kilometres
5 0 10 20 30 40 50 60

Miles and Kilometres.

bituminous in grade and is of a better quality than that of Redcliff. It is used locally for domestic purposes.

Between Chin and Coaldale the railway crosses irrigation ditches, which carry water from one of the branches of the St. Mary river to the south.

108·4 m. 174·4 km. **Lethbridge**—Altitude 2,982 ft. (909 m.). The top of the Belly River series is crossed before reaching Lethbridge and is succeeded by the Pierre shales, sections of which show in the valley of Belly river. Near the water's edge just above the bridge, a coal seam outcrops which is considered to occupy a position at the top of the Belly River series. The valley of the Belly is spanned by a high bridge and from it an excellent view may be had, showing the present stream meandering with gentle current and occasionally swinging into the valley walls and undercutting the softer rocks.

The Lethbridge coal seam is mined in the vicinity of the city. It has a slight dip to the northwest and an average thickness of $4\frac{1}{3}$ feet (1·3 m.).

Four companies are operating at present, namely: the Alberta Railway and Irrigation Company through a shaft 300 feet (91 m.) deep; the Lethbridge Collieries with a shaft 573 feet (174 m.) deep; the Diamond Coal Company by a shaft and a drift tunnel from the river valley; and the Chinook Coal Company through a shaft 425 feet (129 m.) deep. The annual aggregate output amounts to about 400,000 tons.

140·1 m. 244 km. **Macleod**—Altitude 3,128 ft. (953 m.). This town owes its existence to having been originally an outpost of the Royal Northwest Mounted Police.

m. 7 km. **Brocket**—The centre of the synclinal fold in the rocks of the St. Mary River series is crossed about a mile west of Brocket. At Mile Post 173 between Pincher and Cowley, the western limb of the syncline is crosssed.

187·6 m. 301 km. **Burmis**—Altitude 3,815 ft. (1,162 m.). Near Burmis a great fault, with a downthrow to the east, brings the beds of Lower Cretaceous in contact with the upper members.

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## THE CORDILLERA.*

BY

S. J. SCHOFIELD.

### CLASSIFICATION.

The North American Cordillera occupies the western portion of North America from the Great Plains on the east to the Pacific Ocean on the west.

The size of this Cordillera may be indicated by a comparison with the other great mountain chains of the world. The Himalayas cover about 300,000 square miles (777,000 sq. km.), the Alps of Europe about 70,000 square miles (181,000 sq. km.); the Andes about 1,000,000 square miles (2,600,000 sq. km.); and the North American Cordillera over 2,300,000 square miles (5,961,000 sq. km.).

The subdivision of this vast orographic unit in Southern British Columbia and Alberta is based upon topographic features, the lines of delineation being the axes of the greater valleys and trenches in the mountain complex. As can be readily conceived from the accompanying illustration, in the easterly Alpine belt, the Rocky Mountain trench, the Purcell trench, the Selkirk valley and the Okanagan valley represent partial boundaries of the Rocky Mountain, Purcell, Selkirk and Columbia Mountain systems. The Western Alpine belt includes the Coast and Cascade ranges, separated from the Vancouver range and the Olympic mountains by the Strait of Georgia. Between these two Alpine belts lies the more subdued Interior Plateau region.

* Mainly an abstract from Memoir No. 38 by R. A. Daly. Geol. Sur., Can., 1913.

Map to illustrate the paper on the Nomenclature of a part of the
NORTH AMERICAN CORDILLERA
By REGINALD A. DALY.


# GEOLOGICAL HISTORY.

The geological history of the North American Cordillera can be clearly expressed with reference to two large geosynclinals; an eastern or Rocky Mountain geosynclinal and a western or Pacific geosynclinal. It can also be shown that previous to the Mesozoic these two geosynclinals, as regards their relative periods of deposition and erosion, bore reciprocal relations to each other.

The Rocky Mountain geosynclinal lies between the Great Plains and the Purcell trench. It embraces sediments from the base of the Belt (pre-Olenellus) terrane up to and including the Mississippian and is composed of a single group of comformable strata varying in composition and texture according to relative proximity to the ancient shore lines which border such basins of sedimentation. The four type sections which illustrate this principle from east to west are the Lewis Galton, Purcell and Summit series which have an average thickness of about 20,000 feet.

During Triassic, Jurassic and Cretaceous, sedimentation was continuous in the middle and eastern part of the Rocky Mountain geosyncline with a probable increase in the area of sedimentation of at least the Cretaceous beyond the Rocky Mountain geosyncline proper. This period of sedimentation was brought to a close by the Laramide Revolution (Eocene), whose effects are seen in the folding and overthrust faulting so characteristic of the structure of the Rocky Mountain system. Since that time, this belt has been subject to denudation, the detritus of which is seen in the Tertiary and superficial deposits of the piedmont belt of the Great Plains.

Passing to the western or Pacific geosynclinal, which lies between the Purcell Trench and Pacific ocean, the earliest record is the important Pre-Cambrian (Archean) sedimentation, leading to the formation of the Shuswap limestones, schists and gneisses, the latter at least partly of igneous origin. From this time until the Mississipian period, the western geosyncline was an area of erosion, which supplied the material for the formation of the Rocky Mountain geosynclinal. At or near the close of the Mississippian, the western geosyncline area was submerged and received a great load of Pennsylvanian sediments and accompanying lava floods. The record for the Jurassic is meagre, indicating that an upheaval of the Triassic sea bottom had begun as an early preparation for the Jurassic revolution. This was closely followed by the intrusion of many large batholiths of granodiorite and related rocks. Erosion of these Jurassic mountains produced the material for the smaller Cretaceous geosynclinals at various points in the Main Pacific Geosynclinal. Orogenic movements, called the Laramide Revolution, and batholithic intrusion followed.

During the Tertiary, erosion was dominant in this belt with accompanying deposition in isolated basins. Sedimentation was interrupted by local folding in late Miocene and Oligocene. Vulcanism was prevalent throughout the Tertiary while batholithic intrusion was confined to the Miocene.

## GLACIATION.

In that portion of the North American Cordillera, which is embraced by Southern British Columbia and

Alberta, three glacial provinces stand out in bold relief as shown in the accompanying cut. The middle part of the Cordillera was covered by a continuous ice-cap. To the east of this cap, the Alpine belt which includes the greater part of the Rocky Mountain, Purcell, Selkirk and Columbia systems, was covered by numerous valley glaciers whose direction of flow was regulated in the main by the great master longitudinal valleys. Similarly in the Alpine belt lying to the west of the Interior Plateau region, the direction of the ice drainage was governed by the main depressions in that belt. The continental ice-cap of the Interior Plateau region in Southern British Columbia moved in general in a southerly direction.

## PHYSIOGRAPHIC HISTORY.

Foundation for the construction of the present form of the Cordillera was laid at the closing of the Cretaceous period, when the last general orogenic revolution in the Cordillera took place. Mild deformation of the Eocene Oligocene and Miocene formations substantiates the date of this general deformation. The resultant topography superimposed upon a terrane composed of quartzites, hard schists, massive limestones and dolomites, and granites was one of high relief and intricate design. The work of reducing the original chain of early Eocene mountains to the present more subdued relief is of the same order as that accomplished by the erosion of the entire Tertiary period in equally resistant terranes of the Appalachians. The development of the Rocky Mountain and Purcell trenches, the Selkirk and Okanagan valleys, forms a series of tasks comparable to those of opening the Hudson and Connecticut valleys in the east. The many narrow valleys of the Cordillera are analogues of the young to mature Tertiary valleys cut in the Cretaceous peneplain of the Appalachians. During late Tertiary there was an important uplift in the Cordilleran region claimed by Dawson to reach 2,000 feet for the Interior Plateau region. This late Tertiary uplift invigorated the rivers; it did not begin a new erosion cycle at the close of a completed former cycle; hence the entire post-Laramie history belongs to one complex erosion cycle.

# BURMIS, ALBERTA TO ELKO, BRITISH COLUMBIA.

BY

W. W. Leach.

## INTRODUCTION.

The territory lying between Burmis, Alberta and Elko, British Columbia, includes all the coal fields, containing high-grade bituminous coal of Kootenay age in the Crowsnest Pass, which are traversed by the Crowsnest branch of the Canadian Pacific railway.

These fields may be broadly divided into two groups, the most easterly lying in the province of Alberta and separated from the westerly or British Columbia group by the main range of the Rocky mountains. Each of these groups consists of a number of separate areas of coal-bearing beds.

On the Alberta side of the mountains the various coal areas are divided by a series of great faults, following closely the strike of the strata, while the individual areas have been subjected to severe folding and some minor faulting. On the other hand, the British Columbia group is composed of a number of more or less regular basins, the most important of which has a length of some 35 miles (56·3 km.) with a maximum width of 11 miles (17·7 km.).

The coal is contained in rocks of Kootenay age (Lower Cretaceous) consisting of hard, grey sandstones, grey, black, and carbonaceous shales with, towards the top, some hard siliceous conglomerate holding many chert pebbles. In the Alberta group the Kootenay rocks have a total thickness of not more than 700 feet (213 m.) containing from 5 to 6 seams of coal with an aggregate thickness of about 50 feet (15·2 m.) [8], while a section measured near Morrissey, on the British Columbia side of the Pass, showed 3,200 feet (975 m.) of Kootenay rocks with 216 feet (62·7 m.) of coal contained in seams of over 1 foot (·3 m.) in thickness [2]. Similarly the Fernie shales, of Jurassic age, underlying the Kootenay are very much thinner in Alberta than in British Columbia, in the former

having a thickness of about 650 feet (198 m.) while near Fernie, in British Columbia, they attain a thickness of over 3,000 feet (914·3 m.).

The main range of the Rocky mountains, which forms the boundary between Alberta and British Columbia and intervenes between the two groups of coal fields, is composed almost entirely of massive limestone beds which have been determined to be of Devono-Carboniferous age, there apparently having been no break between these twc formations. Towards the top, however, the strata become siliceous containing some thin-bedded quartzites and calcareous sandstones. The total thickness of these rocks has been estimated by G. M. Dawson to be about 4,000 feet (1,219 m.) [1].

The following table shows in descending order the various formations in both groups of coal areas with their respective approximate thicknesses.

Alberta Areas.

| Name of Formation. | Age. | Description. |
|---|---|---|
| Allison Creek (Belly River ?) 1,900 ft. + (579 m.) | Cretaceous.... | Soft, light-coloured sandstones, with small coal seams near top. |
| Benton, 2,750 ft. (838 m.). | | Chiefly dark shales with a few hard, siliceous sandstone beds. |
| Crowsnest Volcanics, 1,150 ft. (350·5 m.)..... | | Trachytic tuffs and breccias |
| Dakota, 2,750 ft. (838 m.)....... | | Chiefly shaly sandstone with plant impressions, usually green in colour. |
| Kootenay 600 ft. (182·8 m.)...... | | Sandstones, shales and coal seams. |
| Fernie, 750 ft. (228·6 m.).. | Jurassic...... | Dark shales with a few thin sandstone beds. |
| Limestone Series, 4,000 ft. (1,219 m.)............. | Devono-Carboniferous. | Massive light-grey limestone. |

BRITISH COLUMBIA AREAS.

| Name of Formation. | Age. | Description. |
|---|---|---|
| Flathead beds........... | Cretaceous.... | Sandy shales and shaly sandstones. |
| Elk Conglomerates, including Flathead beds, 6,500 ft. (1981 m.)..... | | Conglomerates, sandstones, and some semi-cannel coal seams. |
| Kootenay, 1,847 ft. (562·9 m.)............ | | Sandstones, shales and coal seams. |
| Fernie, 3,000 ft. (914·3 m.) | Jurassic....... | Shales, calcareous towards base. |
| Limestone Series, 4,000 ft. (1,219 m.)..... | Devono-Carboniferous | Massive, light grey limestone. |
| ........................ | Cambrian...... | Siliceous argillites. |

There appears to be no great unconformity between the Palæozoic and Mesozoic rocks on either side of the mountains, but the contact between the limestone of the main range and the Allison Creek formation on the eastern slope of the mountains is a faulted one, a great overthrust having caused the limestone to override the Cretaceous sandstone for a distance of several miles. To the east the Kootenay formation is last seen at Burmis station, where another fault of large dimensions with easterly downthrow has brought the Kootenay rocks and Upper Cretaceous strata into juxtaposition.

The coals throughout this district are all of a very similar nature, with the exception of a number of small seams found near Fernie, overlying the main coal measures, which contain coal of a semi-cannel character.

Nearly everywhere the coal cokes readily and is utilized to a large extent in the manufacture of that product; it is generally rather friable, and often contains a somewhat large amount of ash, but it has been found to be eminently

adapted for steam raising purposes and is in much demand by the railways for locomotive use. The following proximate analyses, from air-dried samples, give a general idea of the quality of the coal:—

| Locality. | Moisture. | Vol. Comb. | Fixed Carbon. | Ash. | Remarks. |
|---|---|---|---|---|---|
| (1) Bellevue No. 1 seam.... | 0·2 | 27·5 | 56·8 | 15·5 | Run of mine coal. |
| (2) Coleman No. 4 seam.... | 0·6 | 23·8 | 59·5 | 16·1 | do. do. |
| (3) Michel No. 8 seam.... | 1·1 | 23·8 | 65·0 | 10·1 | Coal, screened and picked at mine. |
| (4) Hosmer No. 8 seam.... | 1·3 | 27·6 | 63·7 | 7·4 | Coal, hand-picked at testing plant. |
| (5) Coal Creek No. 2 seam.... | 1·3 | 26·0 | 63·8 | 8·9 | Coal, screened and picked at mine. |
| (6) Marten Creek | 2·10 | 57·71 | 30·33 | 9·86 | Cannel coal, surface sample. |

Of the above analyses, Nos. 1 to 5 were made at McGill University and have been condensed from the full analyses published in the report on "Coals of Canada" by J. B. Porter and R. J. Durley [**9**].

In the year 1910 a total of 3,137,138 tons (2,000 lbs.) of coal was produced in the district, of which amount Alberta contributed 1,608,205 tons, and British Columbia 1,528,933 tons, from which 121,578 tons of coke were made in the former province and 241,579 in the latter [Refs. **5** and **6**]. In 1911 the output was very much less, due to the fact that for eight months nearly all the mines were idle on account of a miners' strike.

Miles and Kilometres. (fromDunmore) 187·6 m. 301·9 km.

**Burmis**—Altitude 3,995 ft. (1,217·6 m.). Burmis station is almost exactly on the line of a great fault, the strike of which coincides closely with that of the rocks and is nearly north and south, the railway crossing it approximately at right angles. To the east of the station, on the north side, can be seen a series of light-coloured, soft, crumbly, and in places shaly, sandstones, the exact age of which has not been as yet definetely determined,. but is probably well up in the Cretaceous. The fault with its easterly downthrow has brought these rocks against the Kootenay formation showing a throw of at least 7,000 feet (2,133 m.).

A short way to the west of the station, Kootenay rocks are fairly well exposed on the north side of the track consisting of hard, light-coloured and dark grey sandstones, grey and black shales, and coal seams, the latter being overlaid by a massive bed of very hard, light-weathering, siliceous sandstone, in places conglomeratic, which constitutes the top of the Kootenay. The whole of the Kootenay, usually from 650 to 700 feet (198 to 213) in thickness (**1.**), is not shown here, its base, together with the Fernie shales, having been cut off by the fault. In the vicinity of the fault the Kootenay rocks are quite severely folded, good exposures illustrating this are to be seen near the Davenport Coal Company's tipple.

The Davenport Coal Company has developed six coal seams here, the several thicknesses of which are 3·4 feet (1·0 m.), 5 feet (1·5 m.), 4·6 feet (1·4 m.), 5 feet (1·5 m.), 6 feet (1·8 m.), and 6 feet (1·8 m.). The coal is mined by pillar and stall method and hauled to the tipple by endless rope; the steel tipple is equipped with Marcus screens, built at Newcastle-on-Tyne, and is capable of handling 120 tons per hour.

The whole equipment is electrically operated.

After leaving Burmis, the railway follows closely the north bank of the Crowsnest river, good exposures consisting of rocks of the Dakota formation which overlies the coal-bearing Kootenay, being seen for some distance. The Dakota is made up almost entirely of soft, crumbly, dark-coloured, shaly sandstone, and sandy shales often showing obscure plant impressions, the prevailing tints being green, though some very characteristic dark red beds are in evidence. The strata in this neighbourhood are quite extensively folded, and about one mile west of Burmis an important fault occurs with the usual easterly downthrow of several hundred feet.

**Police Flat siding**—At Police Flat is situated one of the Leitch Collieries' plants. This point is on the axis of a sharp anticline and is underlaid by Dakota rocks, but about half a mile to the north, where the mine is situated, erosion has uncovered the underlying Kootenay beds. Here five seams of coal have been proven, 2 ft. (·6 m.), 6 ft. (1·8 m.), 5 ft. (1·5 m.), 4 ft. (1·2 m.), and 10 ft. (3·04 m.), respectively, in thickness. The mine is worked by pillar and stall system and on account of the steep dip (60°) the rooms are driven diagonally up the pitch. The coal is hauled in the main gangway and to the tipple by gasoline motor. The tipple is of the Phillips cross-over type and is equipped with shaking screens and picking tables, and has a capacity of 1000 tons in two shifts. From the tipple the slack coal is elevated to the washing plant, of Luhrig jig type, with a capacity of 500 tons washed coal in ten hours. After washing, the coal passes to bins holding 1000 tons and thence by electric lorries to the coke ovens, 101 in number; these ovens are a modified bee-hive, rectangular in shape and are mechanically levelled and pushed. They take a charge of 10 tons of coal.

Miles and Kilometres.

Leaving Police Flat the railway crosses rocks of Dakota age, showing several well-marked folds until Passburg station is reached, where the Kootenay beds again appear on the Passburg or western limb of a sharp syncline. On the south side of the river, the Leitch Collieries have opened a small mine on a 5 ft. (1·5 m.) seam.

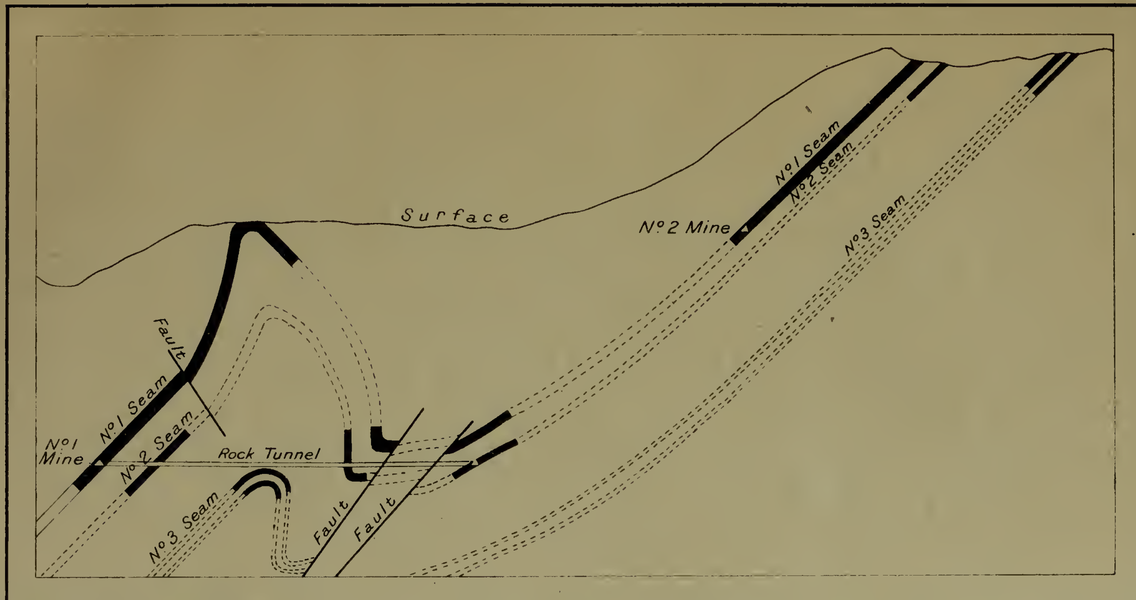
From Passburg to Bellevue siding the railway follows the strike of the rocks, the noticeable steep wall-like ledge on the right-hand side being a massive sandstone immediately overlying the coal measures.

**Bellevue siding**—At Bellevue the West Canadian Collieries Ltd. are operating an important mine. Four seams intersected by a cross-cut tunnel are 9 ft. (2·7 m.), 17 ft. (5·2 m.) $4\frac{3}{4}$ ft. (1·4 m.), and 15 ft. (4·5 m.), respectively, in width, in a total thickness of 450 feet (137 m.) of measures. Two other seams, one 4 ft. (1·2m) the other $3\frac{1}{2}$ft. (1·06 m.) in thickness are known to occur below these. The coal is worked by pillar and stall system, the rooms being driven directly up the pitch. In driving a crosscut from No 1 seam to intersect the lower seams from a point some two miles (3·2 km.) from the entry, a notable double fold was met with, No. 2 seam having been cut in three places while No. 1 and 3 seams were entirely missed; the accompanying sketch will make this clear.

About one half mile (·8 km.) to the east of Bellevue the Maple Leaf mine is situated. The folding mentioned above is well seen here, the coal seams being repeated four times in a disance of about one half mile (·8 km.). The Maple Leaf mine is one of the few places in this district where fossils have been found in the Kootenay rocks, some good specimens of fossil plants having been collected here.

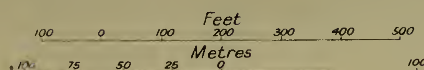
Leaving Bellevue, the railway continues up the Crowsnest river to Hillcrest station, the intervening country being underlaid by Dakota

C2.




Geological Survey, Canada

Section in **Bellevue Mine** showing folding of coal seams



Miles and Kilometres.

rocks, one well defined anticline occurring near Hillcrest station. At this station

193·0 m. **Hillcrest** a short spur turns off to the south
310·6 km. to Hillcrest town and mine. The mine is located on the western limb of a broad undulating syncline on the eastern limb of which the Bellevue mine is situated. Three seams, 14 ft.(4·2 m.), 8 ft. (2·4 m.), and 9 ft. (2·7 m.) in thickness, have been developed at this point

From Hillcrest station to near Frank the Dakota rocks continue, the railway running diagonally across the above mentioned syncline. A short distance west of Hillcrest station the immense Turtle Mountain rock slide is entered. The great gash in the face of Turtle mountain on the south side of the track can be well seen from Hillcrest station. The slide took place early in the morning of April 29, 1903, and besides wiping out the surface works of the Frank mine and imprisoning some 19 miners, demolished a number of houses in the town of Frank. The total loss of life has never been definitely known, but it is believed to have been in the neighbourhood of 70. Two special reports have been written on the subject of this slide, the first by Messrs. McConnell and Brock in 1903 [**3**], and the second in 1911, by a commission appointed to investigate the condition of the mountain at that time [**7**]. The total area covered by slide material is estimated to be about 1·03 square miles, with an average thickness of 45 feet (13·7 m.). It is estimated that about 90,000,000 tons of rock were displaced.

The limestone of the slide is now being utilized in the manufacture of lime.

194·9 m. **Frank**—Just beyond the western edge of
313·7 km. the slide the town of Frank is entered. Here the Kootenay rocks are again met with on the western limb of the same syncline as that at Hillcrest. The Kootenay beds here are nearly vertical or in places slightly overturned so that the dip is 85 degrees to the west. Turtle mountain to the south and Bluff mountain to the

Miles and Kilometres.

north are composed of Devono-Carboniferous limestone, and are on the axis of an overturned and broken anticline, the contact of the limestone and the Kootenay being a faulted one with easterly downthrow, with the result that the lower beds of the Kootenay and all of the Fernie shales are cut off, and do not reach the surface. The Canadian Coal Consolidated is operating two mines at Frank; the first is opened by a drift parallel to the face of Turtle mountain and driven in a southerly direction. Three seams have been proved but one only, the highest, is being worked; this seam is from 12 to 15 feet (3·6 to 4·5 m.) thick. The coal is hauled along the main level and to the tipple by means of gasoline locomotives. The daily output (July, 1912) amounts to about 300 tons.

No. 2 mine is situated about one-half mile north of No. 1 and is being operated by means of a shaft 330 feet (100·5 m.) in depth. The main level, driven from the bottom of the shaft, runs in a northerly direction towards Bluff mountain. From this mine the daily output is about 450 tons.

## LILLE COAL MINE.

From Frank, the Frank and Grassy Mountain railway branches off to the north and follows the valley of Gold creek for about 7 miles. About 5 miles up this line the town of Lille is situated where the West Canadian Collieries are operating their Lille mine. A coal seam 4 to 5 feet (1·2 to 1·5 m.) in thickness has been worked here quite extensively. The mine is operated on the pillar and stall system with compressed air haulage on the main levels, the tipple capacity being about 1,200 tons in two shifts. The company has also a coking plant at this point consisting of a washery for treating the slack coal and a battery of 50 Belgian ovens of the Bernard type.

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194·9 m. **Frank**—On leaving Frank the valley rapidly
313·7 km. contracts, passing through a narrow gorge between Turtle and Bluff mountains, locally known as the "Gap." At its eastern entrance a large brick building was built some years ago by the Canada Metals Company for the reduction of zinc ores from the Slocan district of British Columbia. It has never been operated. A few hundred yards further west, near the contact of the Kootenay and the limestone, a strong sulphur spring occurs, which, although cold, is largely used for medicinal purposes.

About one and one-half miles (2·4 km.) west of Frank the western contact between the Mesozoic and the Palæozoic rocks is reached. In this case the contact is a normal one, the Fernie shales lying apparently conformably on the limestone. This is the only outcrop of the Fernie east of the Rocky mountains on the line of the railway, but, even here exposures are very infrequent owing to the soft and readily weathering nature of the beds, which consist almost entirely of soft dark shales with a few thin arenaceous beds and, towards the top, a notable bed of dark green, very soft, crumbly sandstone. The Kootenay follows the Fernie in regular ascending order, a hard siliceous conglomerate forming its uppermost member which crosses the valley through the town of Blairmore.

196·7 m. **Blairmore**—Altitude 4,226 ft. (1,633·8 m.).
316·5 km. At this point the West Canadian Collieries are operating a mine on the south side of the railway, with an output from 700 to 1,000 tons a day. The coal seams have also been prospected for some distance north of the track. At Blairmore, the Rocky Mountain Cement Company is utilizing the Carboniferous limestone and the Fernie shales in the manufacture of cement; both materials are quarried in open pits and transported to the plant by

Miles and Kilometres.

aerial trams, the proportion of materials used being five parts limestone to one of shale. During 1911 the output of cement from this plant exceeded 100,000 barrels of 350 lbs. each, the daily capacity being about 1,000 barrels. This company also manufactures lime in three kilns near the cement works, the daily production being about 30 tons. The Fernie shales are being utilized also in the the manufacture of brick by the Keystone Portland Cement Company. The bricks made are of the dry press type and the capacity of the plant is about 20,000 bricks daily.

The quarries of these two companies afford the best exposures of the Fernie shales seen in the district and a number of fossils have been collected from them.

For three-quarters of a mile west of Blairmore the railway crosses the strata in regular ascending order when the Blairmore fault is reached, which brings the top of the Kootenay against the upper beds of the Dakota. To the west of the fault the rocks are seen dipping regularly westward, the Dakota overlying the Kootenay and being succeeded by the Crowsnest volcanics, and they by the Benton-Niobrara formation. The volcanics consist of an important intercalation of trachyte tuffs and flows, at this point having a thickness of about 450 feet (137 m.) but rapidly increasing in thickness to the west. The Benton-Niobrara is composed very largely of dark shales, holding marine fossils, with a few hard sandstone beds [8]. It is here about 2,750 feet (838 m.) in thickness. Owing to the soft nature of these shales they have yielded readily to erosion, with the result that they are usually found occupying wide valleys and depressions where exposures are infrequent.

At the eastern end of the town of Coleman, the Benton-Niobrara is succeeded by several hundred feet of soft, whitish sandstone, constituting the base of the Allison sandstones, which is probably referable to the Belly River formation. These beds are cut off by the

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great Coleman fault, which crosses the valley near Coleman station. The fault follows the strike of the strata closely, and has the easterly downthrow usually found in this district, bringing the Kootenay rocks again to the surface.

200·3 m.
322·3 km.

**Coleman**—At Coleman two companies are operating coal mines, one on each side of the valley, The plant and mines of the International Coal and Coke Company (Dennison Colliery) are situated to the south of the railway where five coal seams have been proved, of which No. 2, 15 feet (4·5 m.), and No. 4, 6 feet (1·8 m.) are at present being worked. Both seams are opened by means of levels driven on the strike, the coal being won by pillar and stall method and the rooms driven up the pitch, which is here about 32 degrees.

The capacity of the mine and plant is about 3,000 tons daily.

The coke plant consists of a Bradford breaker and 216 beehive ovens, the coal being delivered to the ovens by electric lorry.

The McGillivray Creek Coal and Coke Company's mine is situated on the north side of the valley about one-half mile from the railway. One seam, from 10 to 12 feet (3 to 3·6 m.) in thickness, the No. 2 of the series, has been developed by means of a slope with levels driven from its foot, the coal being worked by pillar and stall system. From the top of the slope the mine cars are hauled by electric motor along a surface tram to the tipple, a distance of one and one-half miles (2·4 km.). The tipple, of steel construction, is equipped with screens and picking belts and is capable of handling about 2,000 tons in two shifts daily.

In the vicinity of Coleman good sections can be seen of the Kootenay formation on the railway just west of the town and in the bed of Nez Percé creek, near the McGillivray Company's mine, while the Dakota rocks are exposed at frequent intervals for about a mile to the

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west along the road and railway. Overlying the Dakota rocks the Crowsnest volcanics can be well seen in a number of cuts along the railway to the west of Coleman; they here reach a thickness of 1,150 feet (350·5 m.). Specimens from this locality have been microscopically and chemically examined by C. W. Knight who distinguished four predominant rock types, viz.: augite-trachyte breccia, tinguaite, andesite tuff, and analcite-trachyte tuff [**4**].

From Coleman to the east end of Crowsnest lake, the railway crosses the Cretaceous rocks in regular ascending order, the dip of the strata gradually flattening to nearly horizontal. West of Coleman the valley widens, is more open, and shows well-marked terraces, and good views can be obtained of the Rocky mountains and of Crowsnest mountain. This last named peak, by reason of its isolated position, forms a notable landmark for many miles; it reaches an elevation of 9,125 feet (2,780 m.) or about 4,800 feet (1,219 m.) above the valley. The upper part of the mountain is composed of almost horizontal beds of Palæozoic limestone, which have overridden Cretaceous sandstones of the Allison Creek formation along a great thrust plane. The Palæozoic rocks to the east of Crowsnest mountain have been removed by denudation, the valley of Allison creek forming a low depression, underlain by Cretaceous rocks, between Crowsnest mountain and the main range of the Rocky mountains.

204·3 m. **Sentinel**—A short distance beyond the
328·8 km. east end of Crowsnest lake the contact of the Cretaceous and Palæozoic rocks is crossed, the Cretaceous beds dipping under the Devono-Carboniferous limestone along the overthrust fault-plane already mentioned. Half way up the lake, on the north side, a remarkable spring issues from a large overhung grotto in the face of a limestone cliff, and constitutes the chief feeder of the lake.

All along the north shore of the lake as far as the summit, the Palæozoic rocks are well

Crowsnest mountain from near Coleman.

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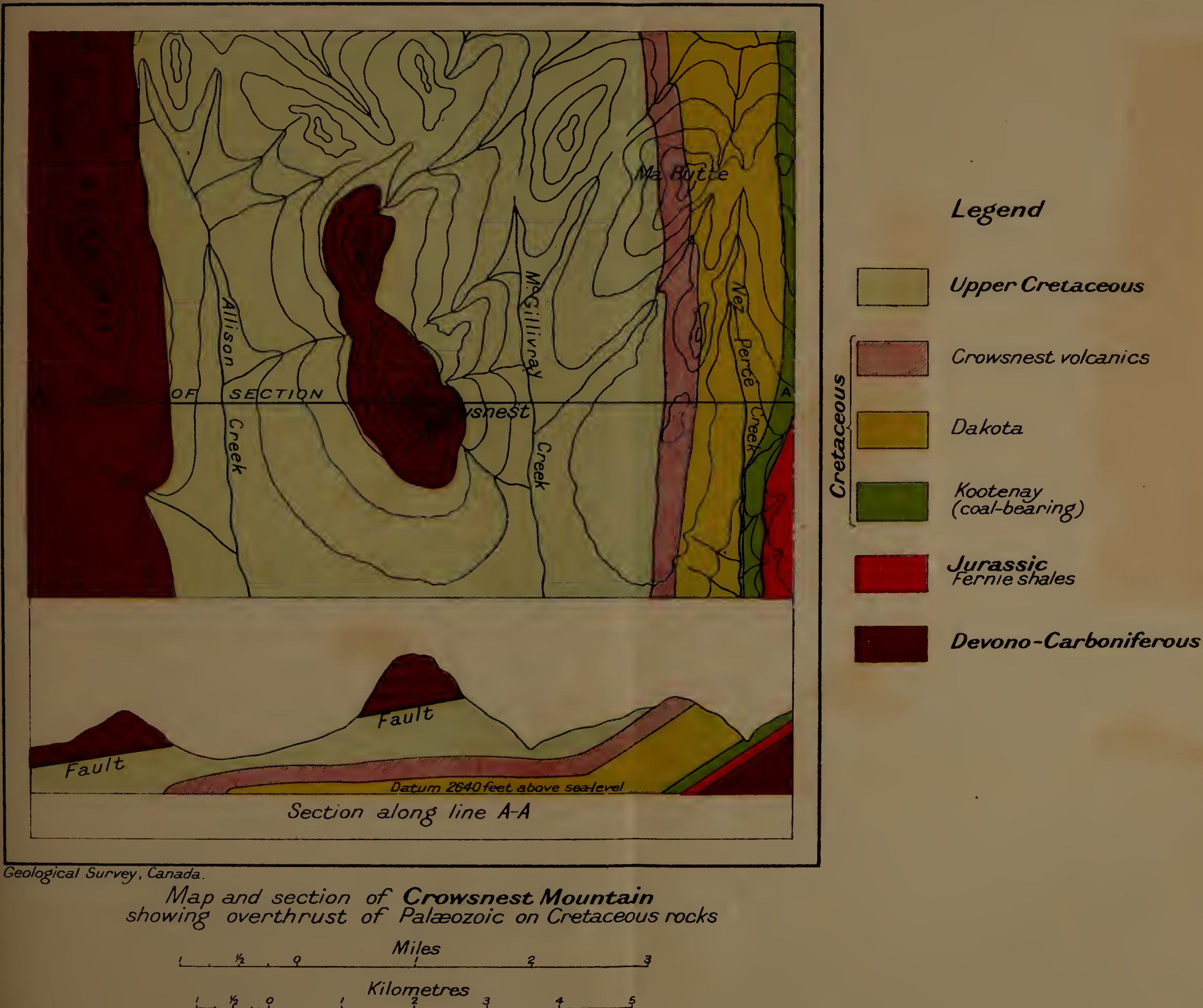
exposed. They consist almost entirely of limestone, usually massive, and often cherty and crinoidal; towards the top of the series a considerable thickness of hard, whitish, calcareous sandstones occurs. The fossils collected from this neighbourhood are mostly characteristic Devonian forms but some of the species represented are known to occur in the Carboniferous. While there is an apparent thickness of nearly 10,000 feet (3,048 m.) of these rocks, it is probable that there is a repetition due to compressed and overturned folding, and that in reality the total thickness does not greatly exceed 3,500 feet (1,067 m.) [**1**].

209·6 m. 337·3 km. **Crowsnest**—Altitude 4,449 ft. (1,356 m.). The summit of the Rocky mountains is reached at Crowsnest station at an elevation of 4,449 feet (1,356 m.) above sea level, being one of the lowest passes in the Canadian Rockies. The western approach to the pass being much steeper than the eastern, the railway descends to the valley of Michel creek by a remarkable loop crossing the south fork of that stream at McGillivray station. From Crowsnest to McGillivray the rocks seen belong almost entirely to the limestone series with two small infolds of the dark-coloured Jurassic Fernie shales.

216·3 m. 348·1 km. **McGillivray**—

## GEOLOGY OF THE REGION ABOUT CORBIN.

From McGillivray the Eastern British Columbia railway branches off, following up the south fork of Michel creek for a distance of 16 miles (25·7 km.) to the town of Corbin. For most of the way it runs in a wide valley, underlain by the Fernie shales, in which rock exposures are infrequent. Tent mountain and Mount Taylor, to the northeast and southwest of the line respectively, are composed of the coal measures overlying the Fernie shales, and occupy small synclinal basins to the east of the main Crowsnest basin.




Geological Survey, Canada.

Map and section of **Crowsnest Mountain** showing overthrust of Palæozoic on Cretaceous rocks

Crowsnest Pass, looking eastward.

**Corbin**—At Corbin a similar outlying remnant of the coal-measures is being exploited by the Corbin Coal and Coke Company. This company is operating two mines; No. 1 being opened near the valley level by means of a tunnel along the strike of the seam, while No. 2 mine is situated nearly 1,000 feet (305 m.) above the floor of the valley. The geological relationship of these two openings has not as yet been worked out, and it is possible that the same seam is represented at both places. At No. 1 mine the seam is nearly vertical and varies greatly in size, from a minimum thickness of 10 feet (3 m.) to a maximum of nearly 250 feet (76·2 m.); this great difference may be due to compressed monoclinal folding. At the upper mine the coal has been stripped near the top of the hill, and shows the coal in a synclinal basin about 370 feet (112·7 m.) in width; the thickness of the coal near the centre of the syncline having been proved by drilling to be over 100 feet (30·5 m.).

The upper mine is reached from the valley by means of a switch-back railway and the coal is worked in open cuts with a steam shovel. The output in 1910 from No. 1 mine alone amounted to about 142,000 tons.

## ANNOTATED GUIDE, (Continued).

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216·3 m. 348·1 km. **McGillivray**—McGillivray station is situated near the eastern edge of the main Crowsnest coal basin, the rocks having general westerly dips. From the station to the junction of the North Fork with the main Michel creek, where the coal measures proper are entered, the railway follows closely the strike of the Fernie shales.

The Crowsnest basin has a total length along its major axis of about 35 miles (10·6 km.) with a maximum width of 11 miles (3·3 km.), and is estimated to cover an area of about 230 square miles (526 sq. km.). In a section measured near Morrissey 22 coal seams, of one foot (0·3 m.) and over in thickness, were noted, containing in the aggregate 216 feet (65·8 m.) of coal in a total thickness of measures of about 3.200 feet (975 m.). The greater part of the coal,

Miles and Kilometres.

however, consisting of 198 feet (60·3 m.), occurs in a thickness of strata of 1,847 feet (562·9 m.) (**2**). Assuming the extent of the basin to be 230 square miles (526 sq. km.) and the average thickness of workable coal at 100 feet (30·4 m.), the total available supply of coal would be about 23,000,000,000 tons. [**2**].

The coal measures are overlain by a great series of conglomerates, sandstones and shales containing, towards the base, thin seams of coal of a semi-cannel nature and reaching a maximum thickness of from 4000 to 5000 feet (1219 to 1524 m.). It is over comparatively limited areas only, however, that such great thicknesses of the overlying beds are to be found, denudation having removed them to a large extent over the greater part of the basin.

Where crossed by the railway in the valley of Michel creek, the basin has narrowed to about four miles (6·4 km.) in width and the beds overlying the coal measures have been entirely removed by erosion.

222·3 m.
357·7 km. **Michel.**—Alt. 3853 ft. (1174·3 m.).

223·8 m.
360·2 km. **Natal.**—

227·5 m.
366·1 km. **Sparwood.**—Alt. 3637 ft. (1108·5 m.).

At Michel, near the centre of the trough, the Crowsnest Pass Coal Company is operating an extensive colliery and coke-making plant. The company has developed seven seams in all, four on the south side of the valley and three on the north side; of the former the seams designated upper No. 3, No. 3, No. 4 and No. 5, have the following respective widths: 10 to 12 ft. (3 to 3·6 m.), 4½ to 5½ ft. (1·3 to 1·6 m.), 6 to 8 ft. (1·8 to 2·4 m.) and 6 to 8 ft. (1·8 to 2·4 m.), while on the north side, No. 7 seam is about 11½ feet (3·5 m.) thick with a 2½ foot (·76 m.) parting; No. 8 is from 8 to 14 (2·4 to 4·2 m.) and No. 9 is about 10 feet (3 m.) thick. No. 9 seam has not been worked for some years. All the mines at Michel, with the exception of No. 3, are worked by the pillar and stall method: in No.

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3 the longwall system is in use. A total of 486 beehive coke ovens have been built at Michel.

From Michel the railway continues down the valley of Michel creek in a northwesterly direction, for a further distance of four miles (6·4 km.) when the wide valley of the Elk river is entered. Elk river here flows in a general southwesterly course and follows closely the strike of the rocks, consisting of the Fernie shales which here reach a much greater thickness than on the eastern side of the Pass. The Fernie shales, of Jurassic age, are composed for the most part of dark shales, often arenaceous, and passing towards the base into shaly limestone and calcareous shales [**2**]. Owing to their soft, non-resistant qualities, they have yielded to pressure more readily than the harder overlying rocks and in consequence are often highly flexed and broken. Good sections of these rocks are also difficult to obtain so that any estimate of their thickness must be only approximate, but it is probable that it exceeds 3000 feet (914 m.).

From the mouth of Michel creek to Morrissey creek, a distance of about 28 miles (45 km.), Elk river follows the upturned edges of the Fernie shales, the high mountains to the west of the valley being built of Devono-Carboniferous limestone, while the western edge of the Cretaceous rocks forms a ridge or escarpment which runs parallel to Elk river on the east side of the valley. The height of the escarpment is fairly uniform, being 3500 to 4000 feet (1067 to 1219 m.) above the river, while the base of the coal measures outcrop at elevations of from 1500 to 2000 feet (457 to 609 m.) above the valley, and dip to the east, at angles of from 30 to 65 degrees.

237·8 m. **Hosmer**—Alt. 3447 ft. (1050·6 m.). At
382·7 km. Hosmer the colliery of the Department of Natural Resources of the Canadian Pacific railway is situated. A rock tunnel, across the measures, has been driven at a point 600 feet

Miles and Kilometres.

(182·8 km.) above the railway for a distance of 4931 feet (1,508 m.) which has cut ten coal seams of the following dimensions:—

| | | |
|---|---|---|
| No. 1 | seam, | 18 feet (5·4 m.). |
| No. 2 | " | 12 feet (3·6 m.). |
| No. 3 | " | 22 feet (6·7 m.). |
| No. 4 | " | 4 feet (1·2 m.). |
| No. 5 | " | 5 feet coal, (1·5 m.).<br>10 inch parting, (25·4 cm.).<br>13 feet coal, (3·9 m.). |
| No. 6 | " | 8 feet 8 ins. (2·6 m.). |
| No. 7 | " | 4 feet (1·2 m.). |
| No. 8 | " | 5 feet (1·5 m.). |
| No. 9 | " | 8 feet (2·4 m.). |
| No. 10 | " | large seam. |

Of these seams Nos. 2, 9 and 10 are at present being worked and it is probable that Nos. 9 and 10 correspond to seams Nos. 2 and 1, respectively, of the Coal Creek colliery. The lowest seams, first cut in the tunnel, have easterly dips of 65° degrees, the dip flattening from there on to a minimum of about 25 degrees. In addition to the tunnel seams, the company is operating a mine on the outcrop of the coal where No. 2 seam is being worked by means of a slope; this point being several hundred feet higher than the tunnel entry.

From the tunnel the coal is lowered to the tipple level by a seam- actuated, double-track incline, and thence hauled to the tipple by air locomotives. The tipple, of steel construction, is equipped with screens and picking belts, and has storage bins with a capacity of 2,600 tons of coal and 2,400 tons of slack. The slack coal is treated in a Robinson washer of 400 tons daily capacity, the washed product being utilized in the manufacture of coke in a battery of 240 beehive ovens.

From Hosmer to Fernie the railway continues along the east bank of Elk river, and occasional exposures of the Fernie shales may be seen.

245·5 m. **Fernie**—Altitude 3,302 ft. (1,006·4 m.).
395·1 km. Fernie, a town of about 5,000 population, is the British Columbia headquarters of the Crowsnest

Mountains west of Elk river near Fernie.

Miles and Kilometres.

Pass Coal Company; from here the Morrissey, Fernie and Michel railway branches off and follows the valley of Coal creek up for a distance of five miles (8 km.) to the Coal Creek colliery.

## GEOLOGY IN THE VICINITY OF COAL CREEK.

Coal creek is a tributary of the Elk river from the east, which occupies a comparatively deep valley cut through the Cretaceous rocks, thus affording a suitable railway grade to the point where the valley floor rises to meet the easterly dipping coal measures. Here the mines are situated. The coal seams strike approximately at right angles to the valley, thus enabling tunnels to be driven on the seams on each side of the creek, while, as this point is approaching the centre of the basin, the seams dip at much lower angles (12 to 18 degrees) than at their outcrop along Elk river escarpment. The company is working five seams here while several others have been prospected to some extent. The seams being worked with their several thicknesses, are as follows:—

| | | | |
|---|---|---|---|
| No. 1 | Average | thickness | 10 feet (3 m.) |
| No. 2 | " | " | 4½ feet (1·37 m.) |
| No. 5 | " | " | 12-14 feet (3·6 to 4·2 m.) |
| A | " | " | 8 feet (2·4 m.) |
| B | " | " | 3½ feet (1·6 m.) |

Seams Nos. 1, 2 and 5 are the ones most extensively worked; Nos. 1 and 5 being opened on the north side of the valley, while three mines are being operated on No. 2 seam, viz.—No. 9 mine on the north side and Nos. 2 and 3 on the south side of the valley. The coal from all the seams except No. 2 is mined by the pillar and stall method, whereas, in the mines on No. 2 seam, the longwall system is in use. Inside the mines, haulage is by horses and air locomotives, while all the coal from the various mines is hauled to the same tipple from the several entries by steam or electric motors. The tipple, a steel structure 840 feet in length, which bridges the valley, is of the Heyl and Patterson revolving side dump pattern, and is capable of handling 4,000 tons daily. It is electrically driven and equipped with the necessary screening and picking appliances. The slack coal is stored in large bins at Fernie and is utilized there in making coke, 452 beehive ovens being in operation.

Miles and Kilometres.

245·5 m. **Fernie**—Altitude 3,302 ft. (1,004·4.). From
395·1 km. Fernie to Morrissey the railway
248·0 m. **Cokato**— continues down Elk river valley,
399·1 km. here wide and flat with few rock
254·0 m. **Morrissey**—exposures. At Morrissey another
408·8 km. branch of the Morrissey, Fernie
and Michel railway leads up the north side of Morrissey creek to the Carbonado colliery of the Crownest Pass Coal company. The Carbonado mines have been idle for some years, although at least nine seams have been worked at different times, and a large plant, including 240 coke ovens, installed. The extremely gaseous nature of the coal at this point, resulting in a number of serious ourbursts of gas, has caused it to be considered expedient to abandon this colliery for the present.

On the south side of Morrissey creek and extending to the south branch of Michel creek on the eastern edge of the coal basin, the Dominion Government holds in reserve a block of 45,000 acres of coal land, being part of a total reserve of 50,000 acres, the remaining 5,000 acres being situated to the northeast of Hosmer.

Shortly after crossing Morrissey creek the railway passes out of the basin of Mesozoic rocks and enters into a belt of Devono-Carboniferous limestones, the valley becoming narrower and rock exposures more frequent. The Palæozoic rocks continue for about five miles (8 km.) when their contact with an older series, consisting of siliceous argillites, possibly of Cambrian age, is crossed. The contact is a faulted one. These beds continue to Elko near which place
263·7 m. **Elko**—Alt. 3,082 ft. (939·4 m.) excellent
424·4 km. sections may be seen in a canyon in the valley
of Elk river.


Geological Survey, Canada

Route map between Lethbridge and Elko

Miles
5 0 10 20 30 40

Kilometres
5 0 10 20 30 40 50 60

Mountains east of Elk river, showing Coal measures near Morrissey.

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# ELKO TO KOOTENAY LAKE, BRITISH COLUMBIA.

BY

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## INTRODUCTION.

The Purcell range, which lies between Elko and Kootenay Lake, is made up of rocks which form the western part of the ancient group of sediments deposited in the Rocky Mountain geosyncline. These sediments, called the Purcell series, consist of a great thickness of fine-grained quartzites, argillaceous quartzites, argillites, and lime-

stones of Pre-Cambrian, and Cambrian age. At various horizons in the above series, shallow water characteristics, including ripple marks, mud cracks, and casts of salt crystals, are very common. The Purcell series extends across the International Boundary line into Idaho and Montana, while to the north geological exploration has, up to this time, been insufficient for the exact determination of its extension in that direction. To the west, on account of batholithic intrusions, the relations are not very clear, but there is sufficient evidence to prove the existence of numerous patches of "Archean" schists on the slopes of the Purcell trench (Kootenay Lake valley). This ancient acidic terrane probably represents part at least of the old land from which the quartzitic Purcell series was derived. The stratified members of the Purcell range pass under the younger formations of the Rocky mountains to the east.

The small cross-cutting bodies of granite and porphyritic granite, which intrude the Purcell series, are considered to be small cupola-like stocks, bearing a genetic relationship to the great West Kootenay granite batholith described in the succeeding section of this guide book.

## TABULAR DESCRIPTION OF FORMATIONS.

| | | |
|---|---|---|
| Pleistocene and Recent | | Unconsolidated gravels and sands. |
| | *Unconformity.* | |
| Jurassic? | | Dyke intrusion: aplites, lamprophyrs and porphyritic granite. |
| | Kootenay granite | Granite and porphyritic granite. |
| Mississippian. | Wardner limestone | Grey limestone. Thickness 1,000 + ft. (305+m.). |
| Devonian | | Limestone and shale. Thickness 500 + ft. (150+m.). |
| Cambrian ? | Roosville formation | Green siliceous argillites. Thickness 600 ft. (183 m.) (Daly). |
| | Phillips formation | Purplish-red and green siliceous argillites and sandstones. Thickness 550 ft. (167 m.) (Daly). |
| | Gateway formation | Light grey quartzites, siliceous dolomites and limestone. Thickness 2,025 ft. (617 m.) (Daly). |
| | Purcell lava | Amygdaloidal basalt. Thicknees 300 ft. (91 m.). |
| | Siyeh formation | Thin-bedded green and purple mud cracked shales; some limestone. Thickness 4,000 ft. (1,220 m.). (Daly). |

| | | |
|---|---|---|
| Pre-Cambrian. | Kitchener formation | Thin-bedded dark grey argillaceous quartzites and limestones. Thickness 4,500 ft. (1,372 m.). |
| | Creston formation | Light grey argillaceous quartzite. and purer quartzites. Thickness 5,000 ft. (1,525 m.). |
| | Aldridge formation | Rusty weathering heavy and thin-bedded argillaceous quartzites and slates. Numerous sills of gabbro at various horizons. Thickness 6,000+ft. (1,830+m.) |

## DESCRIPTION OF FORMATIONS.

### ALDRIDGE FORMATION.

The Aldridge formation is the oldest known sedimentary member of the Purcell series in the Purcell range. It consists of argillaceous quartzites, purer quartzites, and a subsidiary amount of argillite. The beds have an average thickness of 6 inches (15·2 cm.) but vary from a few inches in the argillitic members to eight feet (2·4 m.) in the purer quartzites. The argillaceous quartzites are grey to almost black in colour on fresh fracture. They weather to a rusty brown, and since the argillaceous quartzites are in greater abundance, they give the characteristic reddish-brown colour to the formation as a whole. The thick bedded purer quartzites weather to a light grey colour. Shallow water features, except some conglomerates on Goat river, are not noticed in the Aldridge formation. In places, cubes of pyrite are abundant. A fact, worthy of emphasis, is that in this region the Aldridge formation is characterized by the presence of a relatively large number of thick gabbro sills, called the Purcell sills. The succeeding younger formations contain only a few gabbro sills, and these are relatively thin and unimportant. The Aldridge formation contains the greatest number of economic ore-deposits, and in it are situated the St. Eugene, Society Girl, Aurora, North Star, and Sullivan ore-deposits. Also, the majority of the copper-bearing veins occur in the gabbro sills which are intruded into the Aldridge formation.

## CRESTON FORMATION.

The Creston formation rests conformably upon the Aldridge formation. A transition zone, 500 feet (152·4 m.) in thickness, separates these two formations. The formation consists of a well bedded series of grey argillaceous quartzites, purer quartzites and sandstones with thin intercalations of argillite. The beds are often cemented together so that they form steep cliffs. In the western part of the range these strata resemble coarse sandstones in appearance, while, in the eastern part, the quartzites are finer grained and more argillaceous. The general weathering colour of the lower part of the Creston formation is whitish grey.

## KITCHENER FORMATION.

The Kitchener formation consists of thin bedded calcareous argillites, calcareous quartzites, argillaceous quartzites, and limestones, having a thickness of 4,500 feet (1,368 m.). These strata weather reddish brown. Ripple marks and mud cracks occur in them at several horizons. Intruded into the formation are a few diorite sills, some reaching a thickness of 100 feet (30·5 m.).

## SIYEH FORMATION.

Lying conformably on the Kitchener formation and passing into it by gradual transition is the Siyeh formation, which consists of purple and grey siliceous argillites in beds from 1 inch to 2 inches (2·54 to 5·08 cm.) thick. Some dolomites and limestones are present in the upper part of the formation. The argillites are characterized by the presence of abundant mud cracks and ripple marks.

## PURCELL LAVA.

The Siyeh epoch was brought to a close by the out pouring of a basalt, called the Purcell lava. This lava consists almost entirely of amygdaloidal basalt with small amounts of rhyolite and breccia, and is the extrusive phase of Purcell sills.

## PURCELL SILLS.

The Purcell sills are not only of scientific interest but, economically, they contain small deposits of copper ores. The sills occur as sheets of igneous material from 6 to 2,000 feet (1·8 m.—609 m.) in thickness, intruded between the bedding planes of the quartzites, and occasionally as very small pipes about 400 feet (121·6 m.) in diameter. Most of these sills are composed of gabbro, but a few show great variations within the same magmatic chamber. The same sill, although believed to be simple in character, is heterogeneous in composition, that is to say processes of differentiation have evidently affected the magma of these sills before solidification with the result that the material of some of the sills is stratified according to density. In this case, a granite layer appears at or near the upper contact of the sills, passing downwards into gabbro. The thickness of the granitic layer bears no relation to the thickness of the sill. The sills have probably been affected by all the movements which the enclosing sediments have undergone, and hence occur in all attitudes, from horizontal to vertical. The sills have evidently reached their present stratigraphic position through fissures, although very few dykes have been found within the region examined. The age of these intrusives is probably Cambrian.

## GATEWAY FORMATION.

The lower part of the formation consists of alternating bands of massive concretionary siliceous dolomite and limestone, weathering buff, and massive light grey quartzites. These are succeeded by thin bedded, sandy, argillites and greenish-grey, siliceous, argillites. The sandy argillites weather a light buff and are characterized by the presence of abundant casts of salt crystals.

## PHILLIPS FORMATION.

The Gateway passes gradually into the overlying Phillips formation which consists of dark, purplish, and red metargillites, and sandstones with thin laminae of greenish siliceous argillite intercalated at several horizons.

### ROOSVILLE FORMATION.

The Phillips is overlain conformably by the Roosville, which consists almost entirely of massive, laminated, green, siliceous, metargillites weathering greenish-grey.

### DEVONIAN LIMESTONE.

In the Rocky Mountain system, the Devonian limestone apparently rests conformably upon the underlying Cambrian (?) series, while in the Purcell range to the west, an apparent uncomformity separates the Devonian limestone from the Gateway formation. The staple rock of the Devonian is a massive, dark grey, limestone weathering a whitish-grey colour. The following fossils are found in the limestone:—

Atrypa reticularis.
Spirifer pinionensis.
Orthothetes chemungensis var. arctostriatus.

### WARDNER FORMATION.

The dominant rock of the Wardner formation, which lies conformably upon the Devonian, is a whitish-grey crystalline limestone, occurring in beds from a fraction of a foot to four feet (1·2 m.) in thickness.

The following fossils are contained in the limestone:—
Camarophoria explanata (McChesney)
Camarotoechia cf. C. metallica (White)
Composita madisonensis (Girty)
Cleiothyrdina crassicardinalis (White)
Spirifer cf. S. centronatus (Winchell)
Productella cooperensis (Swallow)

The above fossils point to a Mississippian age, Lower Carboniferous, for the Wardner limestone.

### KOOTENAY GRANITE.

The Kootenay granite, occurring as small stock-like masses, cuts all the members of the Purcell series in East Kootenay. The peculiar alignment of these bodies of granite along the lines of major faulting of the region cannot be accidental. It shows that the intrusion of the

Elk River canyon near Elko, B.C., showing the horizontal argillaceous quartzites of the Roosville formation.

granite magma accompanied or followed the principal orogenic movements which affected the Purcell range. Cutting the granite itself as well as the sediments in the neighbourhood of the granite, are aplite, lamprophyre, and pegmatite dykes which record the last known igneous activity in the Purcell range.

### PLEISTOCENE DEPOSITS.

Lying unconformably on the old eroded surface of all the bed rock formations is a partly consolidated stratified series of clays and sands, into which the streams have incised their beds, leaving well developed terraces at various elevations above their flood plains. In the neighbourhood of the St. Eugene mission two seams of lignite are found in the stratified clays of the Pleistocene.

## REGIONAL STRUCTURE.

The Rocky Mountain geosyncline, which includes the greater part of the Selkirk, Purcell, and Rocky Mountain ranges, consists of Pre-Cambrian, Palæozoic, and Mesozoic sediments. Their western border passes through Cœur d'Alene, Kootenay, and Shuswap lakes, along whose shores is exposed the old crystalline complex, from which part of the above sediments was derived.

The Rocky mountains on the east are separated from the Purcell range on the west by the wide Kootenay-Columbia valley. This topographic feature, which is of first importance in the structure of the region, is called the Rocky Mountain trench. The rocks which form the greater part of the Purcell range are probably Pre-Cambrian in age, and their structure is of an entirely different character to that of the Rockies. The Purcell sediments were first folded into a series of northerly plunging anticlines and synclines. Later these folds were truncated by normal faults which strike in a N.E-S.W. direction and hence trend in a direction at right angles to those of the Rocky mountains. It is probable also that the fault system of the Rockies truncates that of the Purcells, for, in the Rocky Mountain trench, a block of Mississippian limestone is down-faulted in contact with the Pre-Cambrian quartzites, and this block trends in a N.W.-S.E. direction. From the above facts it is probable that the

Elk River canyon near Elko, B.C., looking southwards.

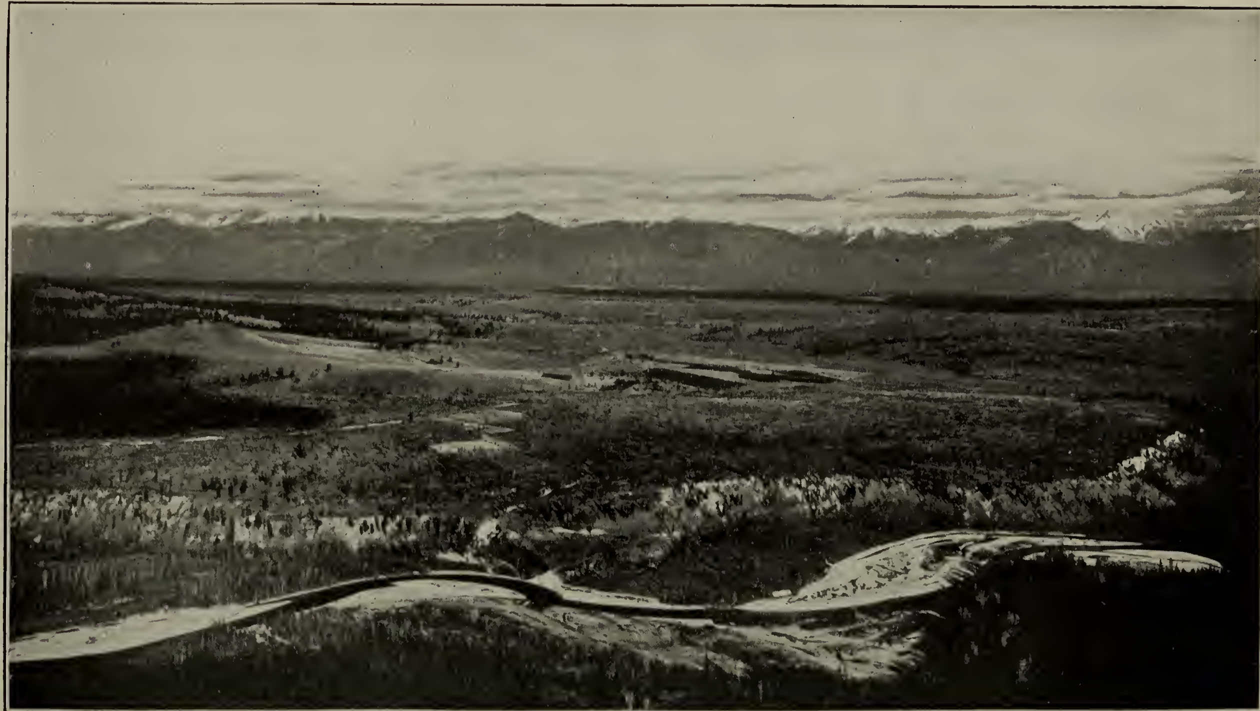
Purcell range was built prior to the Rockies, and that the two ranges are structurally separated by the Rocky Mountain trench.

Miles and Kilometres. (From Dunmore.)

## ANNOTATED GUIDE.

263·7 m. 421·9 km. **Elko.**—Altitude 3,040 ft. (924 m.). On the hill to the north is exposed a section showing the transition from the Cambrian (?) quartzites at the base of the hill to the lower Palæozoic limestones at the summit. Elk river, which above this point had been flowing in a hanging valley, now swings to the southwest, and enters a narrow canyon carved into the flat-lying Cambrian, argillaceous quartzites, and joins Kootenay river at grade about 15 miles, (24 km.) southwest of Elko. At Elko, which is situated on the extreme western edge of the Rocky Mountain system, the Kootenay River valley is entered. The railway pursues a northeasterly course across this valley, whose floor is covered with stratified Pleistocene gravel, sands, and silts. A knob and kettle topography is a prominent feature of this valley. In this floor covering, the Kootenay river has intrenched itself in a meandering course, whose flood plain is wider than its meander belt. The river itself is crossed just before reaching Wardner.

286·7 m. 461·0 km. **Wardner.**—Altitude 2,434 ft. (740 m.). At the end of the railway bridge over the Kootenay, the Mississippian limestone (Lower Carboniferous) is exposed and contains the fossils enumerated on page 51. This limestone is in contact, on its eastern and western boundaries, with the non-fossiliferous Cambrian or Pre-Cambrian argillaceous quartzites. The high range to the east is the western slope of the Rocky mountains which rise wall-like to an elevation of nearly 10,000 feet (3,048 m.). They are composed of Cambrian or Pre-Cambrian sedimentary rocks. From Wardner the railway runs over the Mississippian limestone, which occupies the bottom of the Kootenay valley. From the car the terraces of Kootenay river are distinctly visible.



Kootenay valley, (Rocky Mountain trench) looking eastwards at the abrupt western face of the Rocky mountains.

Miles and
Kilometres.

294·7 m. **Mayook**—The mountain on the left (to
471·5 km. the west) is composed of rocks of the Siyeh formation, and shows outcrops of Purcell lava. From Rampart (298·8 miles, 498 km.) to Eager, (303·7 miles, 506·1 km.) the railway runs through the Isadore canyon, in which are exposed the Creston quartzites, and argillaceous quartzites.

At Eager the railway runs in a south-westerly direction to Cranbrook.

308·7 m. **Cranbrook**—Alt. 2,964 ft. (901 m.). Cran-
493·9 km. brook is the thriving capital of East Kootenay, whose chief industries are mining, lumbering and agriculture. From this point the railway pursues a south-easterly course, crossing, near Cranbrook, the unexposed conformable contact of the Aldridge and Creston formations.

At a point 3·3 miles (5·2 km.) west of Cranbrook is an exposure of the hornblende gabbro of the Purcell sills occurring in the Aldridge formation. Beyond this the sill can be seen outcropping in the steep cliffs on the western side of the railway.

314·1 m. **Loco-**
500·9 km. **Wattsburg**—At Wattsburg, in the hill on
316·8 m. the east side of the railway, can be seen two
506·8 km. gabbro sills intruded into the Aldridge quartzites, which lie approximately flat. Half way up the hill the quartzites are seen separating the two sills. The valley which enters from the west is the pre-glacial valley of Moyie river, which at present occupies a narrow canyon behind the hill to the south-west. From Wattsburg the railway follows the pre-glacial valley, which is eroded in the Aldridge formation. The numerous rock cuts along the railway expose the hornblende gabbro of the Purcell sills. At the crossing of Moyie river, 2·8 miles (4·5 km.) west of Wattsburg, the pre-glacial and post-glacial valleys can be seen. The trough-shaped cross-section of the pre-glacial channel here stands out in contrast

Miles and Kilometres.

with the V-shaped cross-section of the post-glacial channel. At this point the river enters its pre-glacial valley and flows southwards into Upper Moyie lake, where the unexposed fault between the Aldridge and Kitchener formations is crossed.

322·9 m.
516·6 km. **Jerome**—Alt. 2,997 ft. (911 m.). Just before reaching Jerome the train passes through a tunnel driven through the dark grey argillaceous quartzites of the Kitchener formation, which is also exposed in the numerous rock cuts along the shore of the lake. At a point 2·3 miles (3·6 km.) west of Jerome the transition rocks between the Aldridge and Creston formations are exposed.

325·7 m.
521·1 km. Half a mile (0·8 km.) farther west, the rocks show numerous ripple marks and mud cracks. Here also, the railway swings around the nose of the northerly plunging anticline in which Moyie valley has been eroded. The axial part of the anticline is composed of the argillaceous quartzites of the Aldridge formation, while the radial portion is made up of Creston quartzites.

328·6 m.
525·7 km. **Moyie**—Alt. 2,997 ft. (911 m.). From this point the plunging contact between the underlying reddish-brown weathering argillaceous quartzites of the Aldridge formation, and the greyish quartzites of the Creston, can be seen on the mountain side to the west. This contact is the same one noted on Upper Moyie lake. On the hill to the east is situated the famous St. Eugene silver-lead deposit, the value of whose products, up to 1911, amounted to $10,394,520. From Moyie to Yahk the bed rock consists of the argillaceous quartzites of the Aldridge formation which are exposed in the many rock cuts along the railway.

349·5 m.
559·2 km. **Yahk**—Alt. 2,717 ft. (825·9 m.). At a point 1·9 miles (3 km.) west of Yahk the unexposed conformable contact of the Aldridge and Creston formations is crossed. This is the same contact which was crossed on Upper Moyie lake.

Miles and Kilometres.

354·6 m. 567·3 km. **Goatfell**—Alt. 2,857 ft. (868·5 m.). In this vicinity the railway again enters an area of Aldridge argillaceous quartzites, belonging to the same block which was examined at Wattsburg.

364·1 m. 582·5 km. **Kitchener**—Alt. 2,393 ft. (727·4 m.). At a point 3,642 feet (1107 m.) west of Kitchener, a differentiated gabbro sill is exposed in the rock cut. The hornblende gabbro, which occupies the unexposed base of the sill, passes by gradual transition into fine-grained granite, which forms the interior of the sill. The upper portion of the sill is composed of hornblende gabbro.

370·8 m. 593·3 km. **McNellie**—At the crossing of Goat river, about half a mile (1·1 km.) west of McNellie, the Aldridge argillaceous quartzites, which are approximately horizontal, are exposed in the canyon. At this point the river leaves the hanging valley of its upper course, and enters Kootenay river at grade about six miles (10 km.) to the west.

376·2 m. 601·9 km. **Creston**—Alt. 1,942 ft. (590·3 m.). At Creston the delta of Kootenay river is seen. This is the same river which was crossed at Wardner where it pursued a southerly course. It turns in a semicircle in the State of Idaho, U.S.A., and flows north into Kootenay lake at Kootenay Landing.

From Creston the railway runs in a north-westerly direction along the western edge of Kootenay Lake valley, (Purcell Trench). At a point 8·7 miles (13·9 km.) north-west of Creston, the first granite intrusion is met with, and occurs cutting the argillaceous quartzites of the Aldridge formation. As the train proceeds, the amount of granite exposed becomes greater until at Sirdar, the southwestern edge of the West Kootenay granite batholith is reached.

388·5 m. 601·6 km. **Sirdar**—From Sirdar the railway crosses the delta of the Kootenay and arrives at Kootenay Landing.

Miles and Kilometres.

391·7 m. 626·7 km. **Kootenay Landing**—Altitude 1,727 ft. (524 m.). From here a fine view of the delta to the south can be obtained. This valley separates the Purcell range on the east, from the Selkirk system on the west.

**Kootenay Lake**—Kootenay lake occupies the Purcell trench which marks the boundary between the Purcell mountains to the east and the Selkirk system to the west. The lake is about 65 miles (104 km.) long with an average width of about two miles (3 km.). The elevation above sea level is about 1,750 feet (523 m.) and the greatest known depth is 450 feet (137 m). The total area is approximately 220 square miles (7,000 hectares).

The lake is almost straight with a general trend a few degrees west of north. The outlet is through the west arm about 30 miles (48 km.) north of Kootenay Landing. The lake is closely bordered by rugged mountains which slope more or less steeply from the shore and in many cases are fronted with cliffs. The crest lines average over 6,000 feet (1,828 m.) with occasoinal peaks ranging up to 8,000 feet (2,438 m.).

Sandy and gravelly beaches and deltas are found opposite the mouths of the entering streams; elsewhere the shore is rock-bound.

The southern 30 miles (48 km.) of the lake is for the most part eroded in the granitic rocks of the Nelson batholith with the exception of a portion of the east shore between Columbia point and Crawford bay which is underlain by sediments of the Selkirk series striking with the trend of the shore line and showing subordinate strike ridges. Also on the west shore at Proctor and continuing south for 10 miles (16 km.) the Shuswap series is developed, the beds striking northeast and dipping northwest. At Proctor the Shuswap series outcrops on both sides of the lake.


Geological Survey, Canada.

Route map between **Elko** and **Procter**

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# WEST KOOTENAY AND BOUNDARY DISTRICTS

BY

O. E. LeRoy.

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## Geology of the Region between Proctor and Midway.

### INTRODUCTION.

The area embraced by the route map from Proctor to Midway [**1**] lies within the Selkirk and Columbia Mountain systems of the Western Cordillera. The Selkirk system has the Purcell trench (Kootenay lake) as its eastern boundary and the Selkirk valley (Columbia river) as its western. The Columbia system extends westwards from the latter trench to Kettle river [**2**]. The greater part of the area consists of rugged mountainous country which is often alpine in character, tabular reliefs being isolated and comparatively rare. The main ridges trend in various directions and range in elevation from 5,000 to over 6,000 feet (1,524 to 2,133 m.) with peaks from 1,000 to 3,000 feet (304 to 914 m.) higher.

In the Columbia system west of the subordinate trench occupied in part by Christina lake, the mountains are of

a more subdued type characterized by rounded ridges and dome-shaped summits, the average elevation rarely exceeding 5,000 feet (1,524 m). The principal valleys constitute a well marked longitudinal and transverse system which serves as boundaries of subdivisions on mountain groups. The most striking features of the Selkirk system are the Purcell trench occupied by Kootenay lake and the Selkirk valley occupied by Columbia river, and the connecting transverse valley occupied by the West arm of Kootenay lake and its westward extension, Kootenay river.

## GENERAL GEOLOGY.

The main geological divisions are briefly classified in the following table of formations. The smaller geological units, however, have been omitted on the route maps owing the scale of publication.

### Table of Formations.

| | | |
|---|---|---|
| Quaternary | Glacial and Recent. | |
| Tertiary | Miocene | Midway volcanic group. |
| | Oligocene | Kettle river formation, Rossland alkali granite and syenite, Valhalla granite. |
| Mesozoic | Jurassic ? | Nelson batholith. (Rocks range from granite to gabbro). Monzonite. |
| Palæozoic | Carboniferous and Post-Carboniferous | Rossland group. Rocks largely of igneous origin. It includes the Brooklyn and Rawhide formations and the Knob Hill group at Phoenix; the Mount Roberts formation and the augite porphyrite series at Rossland. |
| | Carboniferous (?) | Pend d'Oreille group. (Metamorphosed sediments in great part). Slocan series. (Slates, argillaceous limestones and quartzites). |
| | Cambrian (?) | Selkirk series. |
| Pre-Cambrian | | Shuswap series. (Schists, orthogneisses, etc.). |

### PRE-CAMBRIAN.

The Shuswap series is the oldest known terrane in British Columbia. It consists of a series of gneisses,

crystalline schists, quartzites, crystalline limestones and dolomites with intercalated sills of quartz porphyry, granite, diorite, etc., which are also more or less foliated. According to Dawson and Daly the present condition of the rock series has been effected by static regional metamorphism, the stress directing the crystallization being induced by deep burial and dead weight.

In the vicinity of Proctor on the north side of the west arm the strike of the series is approximately parallel to the shore of Kootenay lake, the prevailing dip being to the west. The west shore of Kootenay lake is the only point in the area where the Shuswap rocks are in direct contact with the immediately succeeding series.

### CAMBRIAN (?).

**Selkirk series**—The formations grouped under the Selkirk series, which has been tentatively referred to the Cambrian, have not been studied in sufficient detail to admit of the series being definitely placed in the geological scale. It is probable, however, that part of the series is Pre-Cambrian. The rocks consist of mica– chlorite– and other schists, bedded quartzites, dolomites and conglomerates, and schistose rocks of distinctly igneous origin. Stocks and masses of diorite, and serpentine, dykes and sheets of acid and basic intrusives and various types of pyroclastic rocks are also included. The structure is distinct in the areas where sedimentaries predominate but much obscured where the rocks are more massive and of igneous origin.

In this area the series overlies the Shuswap and forms a narrow band paralleling the latter along the west shore of Kootenay lake.

### CARBONIFEROUS (?)

**Slocan series**—The Slocan series is tentatively referred to the Carboniferous. It consists of a thick series of argillaceous quartzite, sandstones, argillites more or less carbonaceous, and argillaceous limestones. The rocks are folded and probably much faulted. This can only be inferred from the frequent crush zones as the rocks usually are too uniform in composition to show pronounced contrasts on each side of a fault plane. Along

the margins of batholithic and stock-like intrusions the rocks have been altered to hornstone, andalusite schist, crystalline limestone and lime-silicate rocks rich in garnet. The contact with the Selkirk series is marked by a close fold or fault. Small infolds of the Slocan rocks are of common occurrence in the Selkirk series near the contact. The Slocan series is noted chiefly for the system of fissure veins which contain the important deposits of si ver-lead and zinc ores (see p. 97).

**Pend d'Oreille group**—The Pend d'Oreille group consists of andalusite, quartz and biotite schists, quartzites and crystalline limestones. Though not definitely correlated with the Slocan series the similarity in lithological character would favour the view that the Pend d'Oreille group is a more metamorphosed phase of the Slocan series.

## CARBONIFEROUS AND POST-CARBONIFEROUS.

**Rossland group**—The Rossland group is a complex composed largely of rocks of igneous origin with a minor development of sedimentaries. The igneous rocks are represented by porphyrites, andesites, diabases, agglomerates and tuffs with their schistose equivalents while the sedimentary rocks are mainly slates and limestones, the latter holding obscure Carboniferous fossils. Along the International Boundary there is an apparent unconformity between this group and the Pend d'Oreille group. The group originally included the Mount Roberts formation and the augite porphyrite series at Rossland (p. 85) and the Rawhide and Brooklyn formations and Knob Hill group at Phoenix (p. 75).

**Monzonite**—The monzonites are dark grey to greenish-grey porphyritic or granular mottled rocks, their period of intrusion ranging from Mesozoic to early Tertiary. The intrusions have the form of plugs, dykes and irregular masses approaching batholiths in importance.

## JURASSIC (?)

**Nelson batholith**—The Nelson granodiorite batholith has a very extensive development in West Kootenay district and also extends into East Kootenay and the Boundary district. The granodiorite is intrusive in all

the older formations from Shuswap to the Rossland group. The main mass centres in the vicinity of Nelson while in the outlying areas the batholith is represented by smaller masses and cupola stocks. The contact phenomena are very pronounced for varying widths along the border of intruded rocks, while in the granodiorite the field evidence at many points is excellent in illustration of overhead stoping, differentiation, and absorption of roof and wall rock. The rocks composing it vary from light grey granite to dark grey quartz diorite and even more basic types. A typical and widespread differentiate is a granite porphyry consisting of stout phenocrysts of feldspar 1 to 2 inches (2·5 to 5 cm.) in length in a rather coarse grained base.

An analysis of a specimen from Kokanee mountain by Dr. F. Dittrich of Heidelberg showed the following composition:—

$SiO_2$ 66·46, $TiO_2$ 0·27, $Al_2O_3$ 15·34, $Fe_2O_3$ 1·68, FeO 1·83, CaO 3·43, MgO 1·11, $Na_2O$ 4·86, $K_2O$ 4·58, $H_2O$ 0·29, $P_2O_5$ 0·08—Total 99.93·

The Valhalla granite is closely associated with the rocks composing the Nelson batholith and occurs as large and small intrusive masses within the area underlain by the Nelson batholith. It is probably early Tertiary in age. The rock is a quartzose medium grained light-coloured hornblende or biotite granite with local granodiorite facies.

TERTIARY.

**Rossland alkali granitic rocks**—In this group are included several varieties of intrusive rocks ranging in composition from alkali granite to essexite, the most common type being pulaskite. These intrusives range in importance from dykes and sills to bodies of batholithic proportions, the latter type being well developed along Lower Arrow lake south of Edgewood (see p. 94).

OLIGOCENE.

**Kettle River formation**—The Kettle River formation was laid down during the Oligocene period probably in a broad syncline prepared in early Tertiary. The formation is now represented west of Christina lake by

a series of isolated and somewhat widely separated erosion remnants (see map of Boundary district), the individual units being two small to permit of their delineation on the route map. The rocks composing the formation consists of conglomerates, sandstones and shales with some intercalated tuffs which were laid down in lake and river basins bottomed in most cases by rocks of Palæozoic age. Some of the shales are carbonaceous and contain plant remains and in a few instances thin seams of lignite.

### OLIGOCENE AND MIOCENE.

**Midway Volcanic group** [3]—The Midway Volcanic group consists of a series of lava flows of two distinct volcanic epochs in the Boundary district. The lavas naturally arrange themselves in three groups, the oldest consisting of olivine basalt and augite andesite, the middle group composed of a variety of andesites, and the youngest represented by alkaline trachyte. The oldest and middle groups are referred by Daly to the Oligocene, and the youngest possibly to the Miocene or at any rate after the Kettle River sediments have suffered deformation and erosion.

The lava groups have corresponding intrusive equivalents ranging from augite gabbro to pulaskite porphyry which cut them as dykes, sills and stocks. These volcanics occur in small isolated areas in the eastern part of the Boundary district west of Christina lake, In the vicinity of Midway however, the lavas are extensively developed both to the north and west.

Subsequent warping accompanied by faulting has affected both the Midway Volcanic group and the Kettle River formation.

### QUATERNARY.

The Cordilleran ice sheet covered the whole of southern British Columbia with the exception of some of the higher peaks. In this area the general trend of ice movement was S. 30° E. The ridges were smoothed into rounded and flowing forms, the main valleys were deepened with consequent truncation of spurs and the development of hanging valleys. With the breaking up of the ice sheet

into valley glaciers the smooth and rounded contour of ridge and hill was destroyed by the roughening effect of the latter glaciers which has given the present characteristic alpine topography in areas above the level of the 5,000 foot (1,524 m.) contour. In the vicinity of Nelson well marked glacial striae and groovings have been noted at an elevation of 6,600 feet (2,000 m.) and erratics at 7,184 feet (2,188 m.) above sea level. The slopes are covered with a mantle of varying thickness of drift more or less modified and of "wash". The main valleys are usually flanked by a series of terraces.

## ANNOTATED GUIDE.

(PROCTOR TO CASTLEGAR).

Miles and Kilometres.

**Proctor**—At the entrance to the west arm of Kootenay lake and for about three miles (4·8 km.) to the west, the valley is eroded in rocks of the Slocan, Selkirk and Shuswap series. Westward to and beyond Nelson the valley lies within the area underlain by the granitic rocks of the Nelson batholith. The west arm preserves its lake-like characteristics as far as Nelson though at several points moderate currents have developed due to the encroachment of delta deposits. Just west of Nelson the arm is blocked by boulder drift and a small rapid is developed, marking the continuation of Kootenay river. The rocky bed of the river is but little below the present level of erosion in contradistinction to the bed of the west arm which for the most part has a depth comparable to the main part of Kootenay lake.

0 m.
0 km.

**Nelson**—Altitude, 1,769 ft. (539 m.). The city of Nelson is situated on the delta of Cottonwood creek which flows into the west arm about 22 miles (35·4 km.) west of the main body of Kootenay lake. The city owes its existence primarily to the mining activity in the later 80's and for some years its growth depended wholly on the mining industry. At present, mining, lumbering, manufacturing and fruit ranching are the chief industries and the city is also the

View showing West arm of Kootenay lake, with the towns of Nelson and Fairview, and the deltas of Cottonwood and Anderson creeks, Kokanee peak (9,400 ft.) and glacier (9,060 ft.) in the distance.

Miles and Kilometres.

main distributing centre for the Kootenay and Boundary districts. The city is underlain by granitic rocks of the Nelson batholith near the northern edge of an area of the rocks of the Rossland group [4]. The latter also appear in small isolated patches throughout the main area underlain by the batholith. The ore deposits are all later than the intrusion of the granodiorite batholith (Jurassic?) and younger than the last evidences of igneous activity which form a system of lamprophyric dykes cutting and faulting the ore bodies. The country in the vicinity of Nelson is rather widely mineralized, the principal deposits being gold-silver, silver-copper, silver-lead and copper-gold-silver. The chief mines working at present are the Granite-Poorman (gold), Silver King (silver-copper), Molly Gibson (silver-lead), and the Eureka and Queen Victoria (copper-gold-silver). The total production of the mining division to the end of 1911 amounts to rather more than $10,700,000 in value.

10·8 m. 17 km. **Bonnington Falls**—Alt., 1,658 ft. (505 m). Four miles (6·4 km.) west of Nelson the railway crosses to the north side of Kootenay river. The Kootenay from Granite to Castlegar (22 miles or 35 km.), where it joins the Columbia, has a fall of 335 feet (102 m.), and is characterized by swift-flowing reaches, falls and rapids. The most important falls are at Bonnington, where it is estimated that under a 40-foot head 267,000 H.P. can be developed at low water. At present there are two plants, the West Kootenay Power and Light Company with 20,000 H.P. developed, and the City of Nelson power plant developing 2,350 H.P. The former company supplies power and light to various points in West Kootenay and the Boundary districts, particularly to the mining and metallurgical centres at Trail, Rossland, Grand Forks, Phoenix and Greenwood.

12 m. 19 km. **South Slocan**—Alt., 1,637 ft. (499 m.). South Slocan is the junction point from which a branch railway runs to Slocan city and Slocan lake in

Miles and Kilometres.

Slocan district, which is noted for its silver-lead and zinc deposits. (See p. 96).

26 m. 40 km. **Castlegar**—Alt., 1,418 ft. (432 m). From South Slocan the railway runs west of south, following the right bank of Kootenay river. Castlegar marks the junction of the Columbia and Kootenay rivers which after uniting, flow southwards as the Columbia.

The Columbia rises in Upper Columbia lake and flows north. The Kootenay, rising just east of the westernmost outer range of the Rockies, enters the same valley nearly abreast of the above lake, the distance between the two being about one and a half miles (2·4 km). The Columbia flows north for about 170 miles (274 km.) to the great bend, then southwards through Upper and Lower Arrow lakes to Castlegar, where it is joined by the Kootenay. The latter, after leaving the source of the Columbia, flows southwards into the United States for about 130 miles (209 km). It then takes a westward course turning to the north and empties into Kootenay lake, emerging again as a river just west of Nelson and joining the Columbia at Castlegar.

## ANNOTATED GUIDE (Castlegar to Midway).

At Castlegar the railway crosses the Columbia and follows the south shore of the river and Lower Arrow lake. The rock types exposed are nearly all members of the Nelson batholith with inclusions of the Rossland group.

39 m. 62 km. **Shields**—Alt. 2025 ft. (617 m.). The railway gradually ascends in order to reach the divide separating Lower Arrow lake and Christina lake. Shields approximately marks the contact between the rocks of the Nelson batholith and the Rossland alkali-granitic rocks intrusive into the former. From the spur just west of Shields an excellent view is obtained of that portion of the Columbia valley between Robson and Deer Park.


Geological Survey, Canada.

Route map between **Procter** and **Midway**

Miles 10 5 0 10 20

Kilometres 10 5 0 10 20 30 40

Miles and Kilometres.

50 m. 80 km. **Tunnel**—Alt. 3208 ft. (978 m.). The main ridge is tunnelled through near the western contact of the Rossland alkali granitic intrusion and that of the Nelson batholith. The tunnel is about 0·4 miles (0·6 km.) in length. Its east portal is marked by stratified clays. Four miles (6·4 km.) south of the tunnel is the Big Turtle filled by hydraulicking.

58 m. 93 km. **Farron**—Alt. 3985 ft. (1214 m.). From about a mile (1·6 km.) southwest of the tunnel to a point about three miles (4·8 km.) north of Coryell, the railway traverses the granitic rocks of the Nelson batholith. The cuts show many inclusions of the igneous rocks of the Rossland group and of crystalline limestones. Southwards to the crossing of Kettle river the rocks of the Rossland group are almost continuously developed, associated with minor intrusions of monzonite. The limestone member is well developed in lens-like masses.

77 m. 124 km. **Fife**—Alt. 1978 ft. (603 m.). Near Fife the limestone is quarried and shipped to Trail smelter where it is used for flux.

To the north and south of Fife an excellent view is obtained of the trench occupied by Christina lake (elevation 1450 ft. or 442 m.) and Kettle river. From Kettle river crossing to Grand Forks, the railway follows the river valley, which is underlain by foliated rocks tentatively referred to the Shuswap series.

95 m. 153 km. **Grand Forks**—Alt. 1746 ft. (532 m.). Grand Forks [5] is situated at the junction of Kettle river and its main tributary, the North Fork. The valley is bordered by a series of terraces, and the river meanders in broad curves through the relatively wide bottom.

The smelter of the Granby Consolidated Smelting and Power Company is situated on the North Fork about one mile (1·6 km.) from the centre of the city.

109 m. 175 km. **Eholt**—Alt. 3096 ft. (944 m.). From Grand Forks the railway follows the west side of the valley of the North Fork and an excellent

Miles and Kilometres.

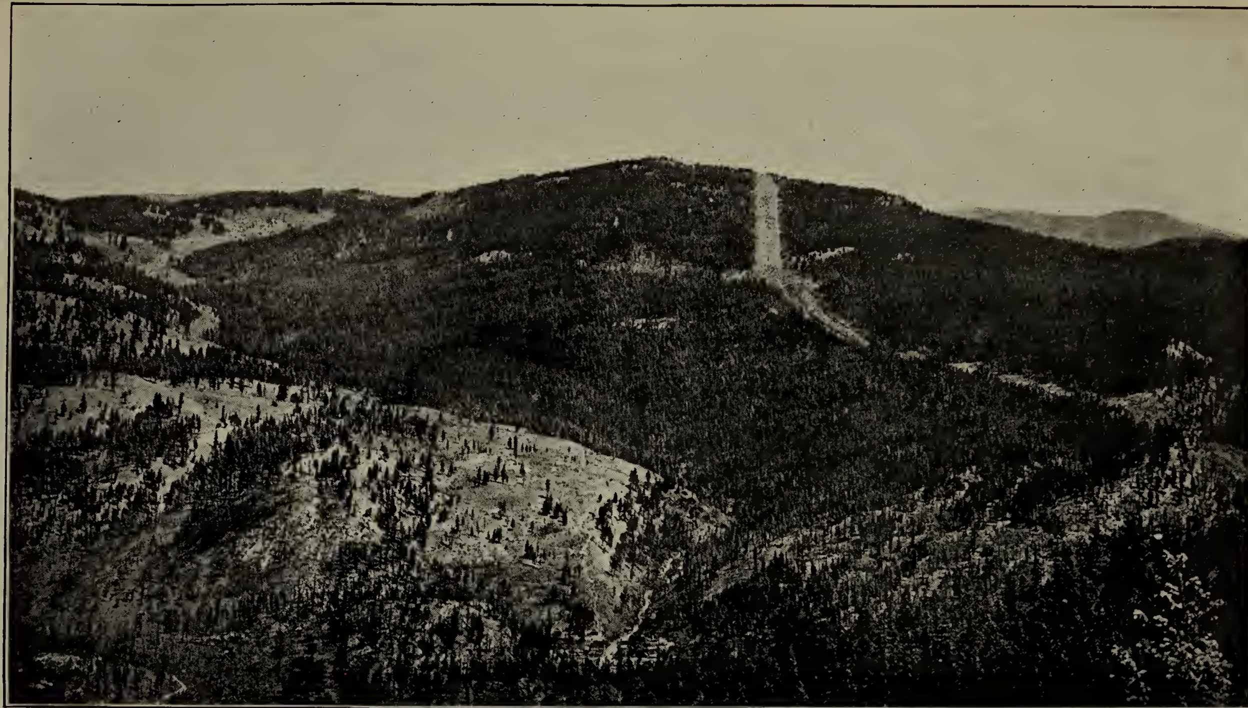
view is obtained of the U-shaped flat-floored valley. The area traversed between Grand Forks and Phoenix, via Eholt, is underlain by several members of the Rossland group, including limestone. Eholt is the junction point from which a branch line goes to Phoenix. About three miles (4·8 km.) south of Eholt the railway crosses the copper and magnetite deposits of the Oro Denoro and Emma mines, the origin of which is similar to those at Phoenix.

## PHOENIX [**6**].

### Introduction.

The production of the Boundary district (including the Osoyoos Mining Division) from 1896 to the end of 1912 amounts to 13,744, 338 tons of ore, containing 938,125 ounces of gold, 5,035,953 ounces of silver, and 334,874,378 pounds of copper, having a gross value of $73,312,913. Approximately 60 per cent of the tonnage was furnished by the mines at Phoenix.

The copper-bearing portion of the Boundary district occupies an area of about 25 square miles (62 sq. km.) and includes the important centres of Phoenix, Greenwood (Deadwood) and Summit. It was in 1891, following the discoveries at Rossland, that prospecting was actively carried on in the three above named camps. In that year most of the ground subsequently proved to be productive was staked. The low grade character of the ore proved a great disappointment which was partially offset by the discovery that the ore was almost self fluxing. The field, however, was open only to large companies with financial resources beyond those of the average individual. The two companies at present operating were early in the field; the Granby Consolidated Mining, Smelting and Power Company confining its attention to Phoenix, and the British Columbia Copper Company operating at Deadwood and Summit. The smelter of the former was built at Grand Forks and the first furnace blown in in 1900. Its capacity has been increased from 1200 tons to between 4000 and 4500 tons per day. The latter company commenced smelting at Greenwood in 1901. The present capacity of its furnaces is about 2600 tons per day.



Typical view of Midway mountains, with Greenwood in the foreground and Phoenix in the basin at the head of Twin creek.

The city of Phoenix is 118·5 miles (190 km.) distant by rail from Nelson, and is 4,600 feet (1402 m.) above sea level. The city lies well within the Midway mountains, a subordinate group of the Columbia system characterized by comparatively low summits which show a uniformity of crest line and they are below the limits of intense alpine erosion.

## General Geology.

The oldest rocks are of Palæozoic age and correspond largely to the Rossland group, a complex of igneous rocks with minor developments of sedimentary types. The structure is very complicated and there is an entire absence of broad or continuous folds. The Mesozoic batholithic intrusives and the consequent crustal disturbances have added to the obscurity of formational relationships. After the Laramide revolution the early Tertiary was characterized by disorganized drainage and vigorous erosion with sedimentation (Oligocene) in the broader basins and with contemporaneous volcanic activity accompanied by later warping and faulting. The later Oligocene and Miocene lava flows were widespread. They were followed by a period of erosion which developed a mature topography with local base levelling followed by uplift. The whole area was further modified by the Cordilleran ice sheet.

*Table of Formations.*

| | | |
|---|---|---|
| Quaternary. | Glacial and Recent. | Clay, sand, gravel. |
| Tertiary...... | Miocene........... | Pulaskite porphyry, Augite porphyrite, Midway volcanic group represented at Phoenix by flows of trachyte. |
| | Oligocene.......... | Kettle river formation, Conglomerate, sandstone, shale. |
| Mesozoic...... | Jurassic (?)........ | Batholithic intrusion, represented at Phoenix by augite syenite and syenite porphyry dykes. |
| Palæozoic .... | Carboniferous ?..... | Attwood series.<br>Rawhide formation.<br>Brooklyn formation.<br>Knob Hill group. |

*Carboniferous ?*

The rocks tentatively grouped under Carboniferous correspond to those of the Rossland group, subdivided at Phoenix into the Knob Hill group and the Attwood series. Their broad structural relation suggests a synclinal fold.

Knob Hill Group—The Knob Hill group consists of a complex of highly altered rocks of igneous origin with minor developments of sediments. The more common types are massive breccias, tuffs and cherts with small lens-like masses of argillite and limestone. Hornblende and augite porphyrites, as dykes and sheets, are less common than in the Rossland area. The most marked feature is the widespread silicification and extensive development of cherty types. The absence of definite structural features prevents an estimate being made of the thickness of the group, but it is known to have a vertical depth of over 1,000 feet (304·8 m.).

Attwood series. Brooklyn formation—The Brooklyn formation overlies the Knob Hill group without any marked stratigraphical break. Originally consisting of limestones with some tuffs and calcareous argillites, the formation now admits of a threefold division based on lithology. The lower zone consists of jasperoids and the upper is composed essentially of lime-silicates (garnet, epidote, etc.), while the limestone forms residual lens-like bodies in both of the above zones.

The jasperoids are derived from limestone tuffs and fine breccias by replacement along planes of bedding, jointing and fracture. They consist of oval, rounded, oblong and subangular pebble-like individuals of crypto-crystalline quartz varying in size from almost microscopic grains to those six inches (15 cm.) or more in diameter. The color is usually dull white or grey, but pink, brown and bright red (jasper) types are locally prevalent. The matrix consists of calcite and shreds of chlorite. Pyrite is usually present. The jasperoids originating from coarse tuffs or breccias contain fragments of different types of volcanic rocks. All transitions are to be seen in the field from the normal limestone to jasperoid in which the original limestone has entirely disappeared.

The zone of lime-silicates is of contact metamorphic origin and consists essentially of garnet and epidote with calcite, quartz and chlorite and trifling amounts of actinolite and zoisite. Irregular lenses and masses of crystalline limestone are also included in the zone and represent unreplaced portions of the original calcareous formation. The zone or rather zones occupy basin-like depressions in the jasperoids. They are for the most part economically important and contain the large bodies of low grade copper ore which have been deposited in certain favourable areas usually along the edge or base of the contact zone.

*Jurassic ?*

The granodiorite batholith so extensively developed throughout the Boundary district and which probably underlies Phoenix at no great depth, is represented at Phoenix by a small stock of augite syenite and two dykes of syenite porphyry which cut the Brooklyn formation.

*Tertiary.*

Oligocene. Kettle River formation.—An isolated area of this formation occurs at Phoenix overlying unconformably the Brooklyn formation and Knob Hill group. The exposure is about one mile (1·6 km.) long and from 40 to 960 feet (12 to 292 m.) wide and 260 feet (80 m.) thick. The formation here consists of conglomerate, coarse and fine feldspathic sandstone, and cherty carbonaceous shales and light grey indurated silts. The strike is northerly and the dips are prevailingly eastward at angles varying from 10 to 60 degrees. The formation has suffered from warping, tilting and erosion before being covered by the Miocene lavas (see section p. 80).

Miocene. Midway Volcanic group.—An erosion remnant of one of the younger lava members of the Midway Volcanic group overlies the Kettle River formation and Knob Hill group. The exposure is a little over a mile (1·6 km.) long and from 1,100 to 2,000 feet (335 to 609 m.) wide. The thickness varies from a few inches (cm.) to about 300 feet (91 m). The rock, though varying in texture from porphyritic to amygdaloidal, is an augite trachyte composed of phenocrysts of orthoclase, soda-orthoclase, andesine, augite and biotite in a base of the same minerals with

additional magnetite and apatite and secondary chlorite and calcite. An analysis by M. F. Connor of the Mines Branch gave the following:—$SiO_2$ 52·64, $Al_2O_3$ 20·69, $Fe_2O_3$ 2·54, FeO 1·82, MgO 1·61, CaO 3·93, $Na_2O$ 4·84 $K_2O$ 5·99, $H_2O+$2·23, $H_2O-$ 0·28, $CO_2$ 0·75, $TiO_2$ 0·64, $P_2O_5$ 0·41, MnO 0·07, SrO 0·21, BaO 0·60=99·25.

According to the quantitative classification the rock falls in class persalane, order russare, rang viezzenare, subrang, procenose.

The augite trachyte lava and all the older rocks are cut by sills, dykes and stocks of augite porphyrite and pulaskite porphyry, the latter being the younger. The augite porphyrite is dark grey in colour with a porphyritic texture approaching granitoid. It consists of dark grey tabular phenocrysts of orthoclase and plagioclase—the latter being between andesine and labradorite,—augite, brown hornblende and biotite in a base which is largely feldspathic. Apatite and magnetite are also present as well as a small amount of quartz.

The pulaskite porphyry is light grey, weathering to pink or pale red, with characteristic rosette-like clusters of white feldspars in a fine-grained highly feldspathic base.

The phenocrysts are soda-orthoclase, oligoclase and acid andesine. The larger individuals are surrounded by a zonal crust of clear orthoclase. The augite and biotite individuals are largely altered to granular carbonates with chlorite and magnetite. Hornblende, quartz, apatite and magnetite are present as accessories.

Analyses of the augite porphyrite and pulaskite porphyry were made by M.F. Connor of the Mines Branch. The former is under Column I the latter under II.

| | I. | II. |
|---|---|---|
| $SiO_2$ | 55·90 | 57·32 |
| $Al_2O_3$ | 15·52 | 17·27 |
| $Fe_2O_3$ | 1·22 | 1·62 |
| FeO | 5·22 | 3·94 |
| MgO | 4·70 | 2·68 |
| CaO | 5·79 | 4·24 |
| $Na_2O$ | 2·89 | 4·52 |
| $K_2O$ | 4·45 | 5·96 |
| $H_2O+$ | 1·40 | 0·47 |
| $H_2O-$ | 0·60 | 0·08 |
| $CO_2$ | 0·14 | ........ |

| | | |
|---|---|---|
| $TiO_2$ | 0·90 | 0·88 |
| $P_2O_5$ | 0·46 | 0·51 |
| MnO | 0·08 | 0·09 |
| SrO | 0·09 | 0·06 |
| BaO | | 0·24 |
| | 99·36 | 99·88 |

I. Class dosalane, order germanare, rang andase, subrang shoshonose.

II. Class dosalane, order germanare, rang monzonase, subrang monzonose.

*Glacial and Recent.*

The area about Phoenix is free from any thick or continuous mantle of drift. Cuttings in the valley of Twin creek show rudely stratified sands, clays and gravels. The surrounding ridges are glaciated to their crests, the striae having a direction of S. 26° E.

ORE DEPOSITS.

The copper deposits occur at intervals along the edges of the zones of contact metamorphism and also at the base of the zone or in some non-outcropping intermediate position.

The zone in which the principal deposits occur is horseshoe-shaped. The west limb is 3,200 feet (975 m.) long and 1,000 feet (304 m.) wide, while the east limb is 2,250 feet (686 m.) long and from 350 to 1,000 feet (107 to 304 m.) wide. The thickness varies from one foot (30 cm.) or so to 350 (106 m.). The floor is jasperoid or in places the siliceous rocks of the Knob Hill group.

*Knob Hill-Ironsides mine*—The ore body of the above mine owned by the Granby Consolidated, is the largest and most typical of the camp. The ore body is composite in character and consists of two lenses which coalesce about their central portions. Along the outcrop these appear as distinct ore bodies separated by a varying thickness of the lime-silicate gangue rock (see section). The western lens is at least 2,500 feet (762 m.) long, from 370 to over 900 feet (113

Portion of glory hole, Knob Hill and Ironsides mine, Phoenix.

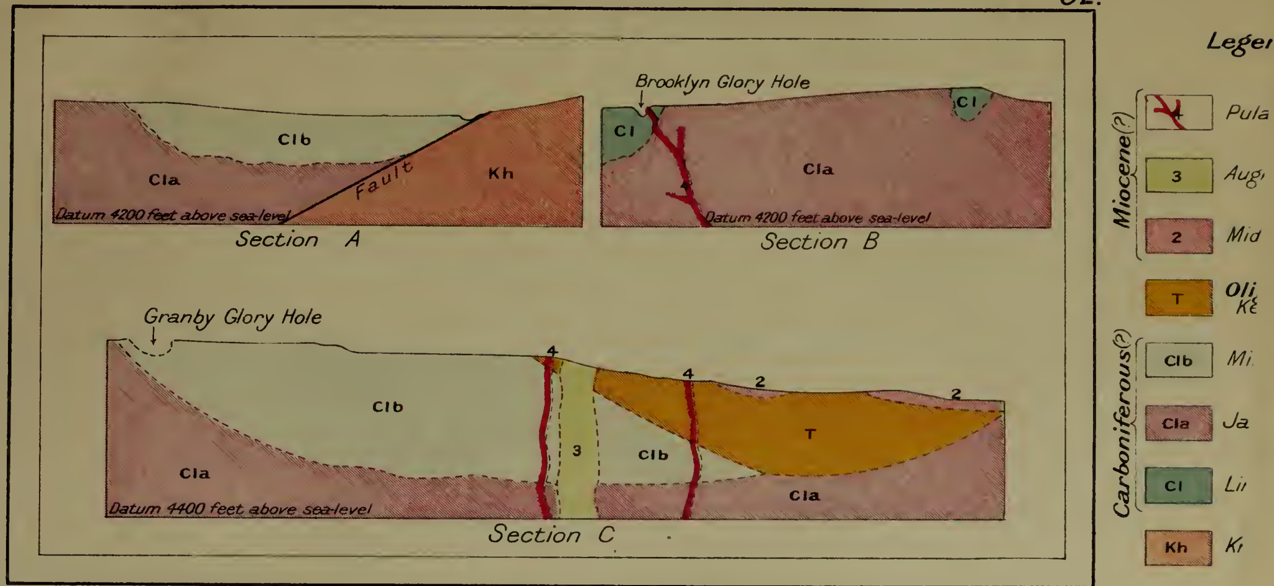
to 274 m.) wide, and from 40 to 125 feet (12 to 38 m.) thick. The eastern lens is apparently shorter but approaches the magnitude of the other in width and thickness. The general strike along the outcrop is about N. 10° E. with dips to the east ranging from 45 to 60 degrees. The dip flattens with depth and on the lower levels averages from 15 to 30 degrees. The general pitch of the ore bodies is about 18 degrees to the northeast. The vertical range from the south end of the main "glory hole" to the lowest working levels is 675 feet (206 m.). The structural footwall is the jasperoid zone of the Brooklyn formation, and in places, the siliceous rocks of the Knob Hill group. The hanging wall is a purely commercial one and the ore either grades insensibly into barren gangue or terminates sharply against a gouge-filled fissure. The ore bodies and adjacent rocks are traversed by an intricate system of fissures which run in all directions and dip at all angles. They have had a most important influence on ore deposition as they formed channels for the ore-bearing solutions which permitted a uniform distribution of their metallic contents. In many cases the ore adjacent to these fissures is of noticeably higher grade. Some of the fissures have been subsequently filled with banded quartz, calcite and chalcopyrite.

The only displacement noted is along one of the major fissures which faulted the ore body with a throw varying from zero to 120 feet (36 m.) along a dip of 55 degrees to the west. (See section).

The ore is mainly massive with local banded areas. It consists of chalcopyrite, which with pyrite and hematite is finely and uniformly distributed through a gangue composed almost exclusively of garnet, epidote, quartz, calcite and chlorite. The pyrite occurs in grains, crystals and streaks, while the hematite (specularite) occurs in platy aggregates. Magnetite occurs in masses and irregular lenses at intervals through the ore bodies but it is relatively unimportant. The average content of the ore is: copper 1·25 per cent; gold 0·04 ounces and silver 0·3 ounce per ton. Along the outcrop the ore has been leached out in part but has produced no noticeable secondary enrichment at lower levels.

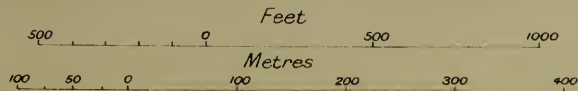
The zone of contact metamorphism and the development of lime-silicates is believed to have been the result of metasomatic replacement of limestone by solutions

C2.




Geological Survey, Canada.

***Phœnix***—*Structural sections illustrating the relations of the mineralized zone and the country rocks*



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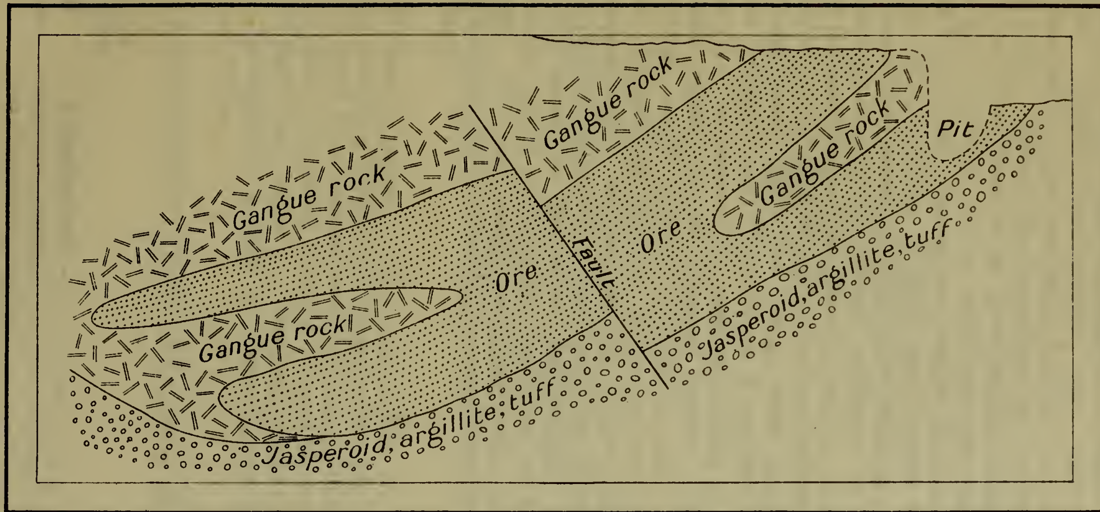
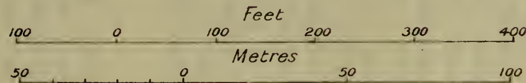



Geological Survey, Canada

Section across ore-body, **Knob Hill-Ironside Mine**



above the critical temperature carrying ferric iron, alumina and silica and consisting mainly of water gas strongly ionized. Epidote and garnet, etc., were formed, and the magnetite was probably formed contemporaneously with them. When the formation of the above was well advanced the character of the solutions changed somewhat and chalcopyrite, pyrite and hematite were deposited in and along the numerous minute fissures and cavities in the lime-silicates. Calcite and quartz were the last to deposit and completely filled the remaining minute spaces. In the absence of any direct evidence, as there are no large bodies of igneous plutonic rock in contact with or adjacent to the zone of contact metamorphism at present, it is suggested that these zones were overlain by more or less irregular and thick sheets of granitic rock and that these were the cause of the metamorphism of the limestone and the source of the mineral bearing solutions. The circulation would thus be descending and laterally and would account for the ore bodies terminating abruptly at comparatively shallow depths either against jasperoid or crystalline limestone. The age of the deposit is referred to post-Jurassic or the period immediately following the intrusions of the granodiorite batholith of the Boundary district. The ore bodies suffered from erosion in the early Tertiary and are overlain unconformably by Oligocene sediments.

*Method of Mining.*—The ore bodies are mined along their outcrops by large open quarries or "glory holes" and underground by a system of tunnels and shafts. Stoping by the pillar and room method is used entirely below the level of the "glory holes". The development work is based on the information gained by extensive prospecting with diamond drills.

## ANNOTATED GUIDE (Phoenix to Midway.)

Miles and Kilometres.

117 m.
188 km. **Greenwood**—Alt. 2 464 ft. (751 m.). Greenwood is situated in the valley of Boundary creek about four miles (6·4 km.) west of Phoenix. The valley at this point is deeply eroded in granodiorite which underlies and surrounds

Miles and Kilometres.

the town. The British Columbia Copper Company's smelter is situated at Anaconda which joins Greenwood to the south. The Mother Lode mine of the same company is at Deadwood about 2·5 miles (4 km.) northwest of Greenwood. The copper deposits at Deadwood are similar to those at Phoenix.

127 m. 206 km. **Midway**—Alt. 1,913 ft. (580 m.). Midway lies well within an area underlain by the lavas of the Midway Volcanic group. The town is situated in the broad bottom lands of the Kettle River valley, flanked by terraces and backed by low rounded and conical hills of lava. Boundary creek flows on bed rock between Greenwood and Midway, and near the junction with the Kettle, it has trenched itself in a box canyon with walls of lava.

## ANNOTATED GUIDE (Castlegar to Rossland.)

0 m. 0 km **Castlegar**—Between Castlegar and Smelter the bed rock is mainly the granodiorite of the Nelson batholith with the exception of an area of gneisses and schists (Shuswap series) between Blueberry and Sullivan creeks. Along this portion of Columbia valley, the rock is extensively covered by a system of well-defined terraces composed of horizontally bedded sands and sandy clays. To the south of Castlegar, the valley is relatively broad and the bottom lands and terraces support a flourishing fruit industry.

44 m. 71 km. **Smelter**—Alt. 1,565 ft. (467 m.). The smelter and lead refinery of the Consolidated Mining and Smelting Company is situated at Smelter. It is the most important metallurgical centre in British Columbia. The gold-copper ores of Rossland and the silver-lead ores of the Slocan are treated here, and in the case of the latter, the final product is refined silver and lead.

Miles and Kilometres.

The town of Trail lies about 200 feet (61 m.) below Smelter at the junction of the Columbia valley and Trail creek.

## ROSSLAND [7].

### Introduction.

Rossland is situated about six miles (9·6 km.) west of Columbia river and five miles (8 km.) north of the International Boundary. The main avenue of the city is 3,410 feet (1,039 m.) above sea level. The city lies on the slopes of Red and Monte Christo mountains towards the head of Trail creek. The immediate surrounding country is characterized by mountains with rounded peaks and gentle, flowing slopes. The city commands a view of Trail Creek gulch, the Columbia valley 2000 feet (609 m.) below, the Selkirk mountains to the east and the ranges in Northern Idaho and Washington to the south.

The first discovery near Rossland was made on the Dewdney trail in 1887 when the Lily May claim was staked. In 1890 the LeRoi, Centre Star, War Eagle, and other mines were staked on Red mountain, and a small lot of ore was packed out in 1891 and shipped to an American smelter.

The total production from 1894 to 1912 inclusive, according to the Provincial Bureau of Mines, amounts to 4,105,358 tons, containing 1,995,589 ounces of gold, 3,381,421 ounces of silver and 86,608,170 pounds of copper. The gross value is placed at $55,100,259.

The principal mines at present are the LeRoi, War-Eagle, Centre Star group, owned and operated by the Consolidated Mining and Smelting Company and the LeRoi No. 2 Company. The greatest depth reached is 2,200 feet (670·5 m.) below the surface outcrops, and all ore mined is shipped to Trail for treatment.

### GENERAL GEOLOGY.

In 1894 R. G. McConnell made a reconnaissance survey of Rossland for the Geological Survey, and in 1905 and 1906, R. W. Brock, assisted by G. A. Young, made detailed geological maps and mine examinations.

The geology of Rossland centres around a mass of monzonite which is rudely oval in form with the east and west axis about five miles (8 km.) in length. The mass is intrusive into the rocks of the Rossland group, which has been subdivided into a sedimentary and igneous series.

*Table of Formations.*

| | | |
|---|---|---|
| Quarternary | | Glacial and Recent. |
| Tertiary | | Pulaskite. |
| Mesozoic | Post-Jurassic ? | Lamprophyric dykes. |
| | | Serpentine. |
| | | Nelson granodiorite and granite porphyry. |
| | Jurassic ? | Porphyritic monzonite. |
| | | Diorite porphyrite. |
| | | Monzonite. |
| | Triassic ? | Volcanic agglomerate. |
| Palæozoic | Carboniferous | Augite porphyrite. |
| | (Rossland group). | Mount Roberts formation. |

## *Carboniferous.*

Mount Roberts formation—The Mount Roberts formation is developed chiefly in two bands, the broader one lying on the western slopes of Red mountain, while the narrower one lies further to the west, separated by a band of igneous rocks. The formation consists of black slates, in part carbonaceous, with arenaceous and calcareous varieties interbedded with lighter coloured types. There is a frequent interbanding of darker varieties with lighter coloured and more siliceous types some of which are probably of tufaceous origin. Fossils have been collected in one locality and though poorly preserved have been identified as Carboniferous types.

The strike of the formation is northerly with a general dip to the west which steepens on going westward. In the western band the beds are vertical, which is probably due to a fault. The sediments are extensively faulted in an east and west direction with throws varying from a fraction of an inch to several feet. Breccias are common along the contact of the sediments with the granodiorite and porphyrite.

Augite porphyrite.—The augite porphyrite series forms a large part of the area originally mapped as the Rossland volcanic group. It occupies four main areas on the map sheet and is intrusive in the Mount Roberts formation. The structures and textural characteristics of the rock shows that it probably occurred as surface flows and sills. In places the rock is interbanded with fine-grained beds which are probably tuffs. In other places it presents an agglomerate phase of two eruptions. The typical rock is dark grey to greenish black, studded with stout prisms of pyroxene and hornblende imbedded in a dark ground-mass composed chiefly of small laths and grains of labradorite and hornblende. The rock is both massive and sheared and in places is highly altered. An analysis of a type from the War Eagle is as follows:—

$SiO_2$ 50·89, $TiO_2$ 0·80, $Al_2O_3$ 17·00, $Fe_2O_3$ 0·97, FeO 7·60, MnO 0·14, MgO 5·41, CaO 9·82, $K_2O$ 1·31, $Na_2O$ 3·35, $H_2O-$ 0·06, $H_2O+$1·14, $P_2O_5$ 0·19, S 0·43, $CO_2$ 0·28 = Total 99·39.

## *Triassic?*

The Volcanic agglomerate of probably Triassic age overlies the Mount Roberts formation, apparently conformably. The outcrop is lenticular in form and coincides in strike and vertical dip with the underlying slates. The formation suffered with the Carboniferous in the crustal disturbances of the Jurassic revolution.

The agglomerate is composed of fragmental material including quartz, slate and altered volcanic rocks. The formation also includes some tufaceous beds. There is a rough assortment of the material in certain beds, in which cases the longer axis of the fragments coincide with the general strike of the formation.

## *Jurassic?*

Monzonite.—The monzonite intrusions, in the forms of masses and dykes, are composed of a number of closely related varieties of slightly different ages which underlie about one half of the Rossland map-area. The intrusive masses have an east and west trend and have possibly followed a profound structural break. The structural relations show that the intrusion was subsequent to the

crustal disturbances which tilted and folded the Carboniferous rocks. The main intrusions may at points have originally reached the surface through the Carboniferous sediments and appeared as a volcano or a series of volcanoes. The three principal types in order of age, commencing with the oldest, are monzonite, diorite porphyrite and porphyritic monzonite. In general, the coarser types are younger than the fine-grained ones, and the more feldspathic younger than the basic types.

The normal monzonite shows considerable variation in different parts of the same mass. The rock varies from grey to black in colour, and from granitoid to semi-porphyritic in texture. The coarser types consist of black prisms of pyroxene or secondary hornblende, flakes of brown biotite and a light coloured plagioclase feldspar which is often labradorite. The microscope discloses in addition some alkali feldspar, magnetite and apatite. At times local variations show an almost total disappearance of the feldspar, in which case the bulk of the rock is made up of augite and hornblende. In the finer grained varieties, the granular white feldspathic groundmass is peppered with tiny grains and small prismatic individuals of the dark constituents which gives a characterisitic mottled aspect to the rock.

The following analysis of the monzonite from the 700-foot level of the Le Roi mine was made by the Mines Branch.

$SiO_2$ 54·49, $TiO_2$ 0·70, $Al_2O_3$ 16·51, $Fe_2O_3$ 2·79, FeO 5·20, MnO 0·10, MgO 3·55, CaO 7·06, $K_2O$ 4·36, $Na_2O$ 3·50, $H_2O$— 0·07, $H_2O$+ 1·18, $P_2O_5$ 0·20, S 0·23, C $O_2$ 0·24.

Diorite porphyrite.—The diorite porphyrite occurs in oval, dyke-like forms expanding into larger masses. It is probably younger than the normal monzonite but field evidence is not clear on this point. It is cut by dykes of porphyritic monzonite. Mineralogically the rock might be regarded as a phase of the monzonite. It varies from light grey to greenish black. The texture ranges from porphyritic to fine granitoid. The rock consists of phenocrysts of plagioclase feldspar (andesine to acid labradorite), pyroxene and hornblende lying in a groundmass of feldspar, quartz and hornblende, the relative amounts of these constituents fluctuating widely.

Porphyritic monzonite.—The porphyritic monzonite occurs in masses and dyke-like bodies. The outlines of some of the masses suggest in cross-section, pipe-like chambers extending upwards through the Carboniferous rocks and may possibly be portions of old volcanic conduits. In some of its phases the rock resembles types of the coarse monzonite. It is light grey and coarse in grain with large stout prisms of green pyroxene, secondary horblende, countless small rounded hexagonal flakes of brown biotite and abundant andesine feldspar. Another type consists essentially of augite, biotite, an alkali feldspar and acid labradorite.

*Post-Jurassic (?)*

Nelson granodiorite and granite-porphyry.—The important batholithic intrusion which underlies hundreds of square miles in West Kootenay is represented on the Rossland map by one irregular area and several small masses with related dykes of granite porphyry. The rock is light grey in colour, of uniform grain and is composed of biotite, hornblende, quartz and abundant feldspar chiefly of the plagioclase varieties. The age, as far as the development at Rossland is concerned, can only be referred generally to the period following the Jurassic orogenic movement and prior to the instrusions of pulaskite of the Tertiary.

Serpentine.—The outlines of the serpentine areas in the vicinity of Rossland suggest vertical stocks or necks intruded into the disturbed and highly inclined sediments and porphyrites of the Carboniferous. They appear to occur along the probable line of weakness followed by the intrusions of the monzonite. The exact age of these altered basic plutonics has not been determined beyond the fact that they are older than the Tertiary pulaskite.

Lamprophyric dykes.—The monzonite and granodiorite intrusions were followed by fissuring and dyking on an extensive scale. A general northerly trend is preserved by the dykes although they cross, branch and coalesce in a very intricate manner. The total number of dykes must be very great for in some of the underground workings of the mines they occur on an average of one in

every 25 feet (7·5 m.). The principal varieties are typical minettes, kersantites, vogesites and odonites with many intermediate forms [**1**]. Aplitic dykes also occur which may be complementary to the more basic types.

*Tertiary.*

Pulaskite.—The pulaskite or alkali syenite occurs in irregular, elliptical and dyke-like masses intrusive in all the older rocks. Some of the present outcropping masses may represent deeply eroded conduits of ancient volcanoes. The normal rock is coarse in grain and pale pink in colour. It is composed essentially of long rectangular feldspars (intergrowths of orthoclase and albite) with biotite and hornblende, though neither of the two latter are abundant. An analysis by Dr. F. Dittrich, Heidelberg, gave the following:—

$SiO_2$ 62·59, $TiO_2$ 0·54, $Al_2O_3$ 17·23, $Fe_2O_3$ 1·51, FeO 2·02, MnO tr., MgO 1·30, CaO 1·99, $K_2O$ 6·74, $Na_2O$ 5·50, $P_2O_5$ 0·11, $H_2O$ 0·30, $CO_2$ tr., Cl tr., $SO_3$ tr. = 99·83.

The rock is closely related in every respect to similar intrusions at Phoenix and elsewhere in the Boundary district which are of Miocene age.

## ORE DEPOSITS.

There are two mineralized belts in the Rossland camp known as the North and South belts respectively. The North belt is by far the most important. All the rocks except perhaps the later dykes are more or less mineralized, but the large ore bodies are confined mainly to the Carboniferous augite porphyrites and the monzonite, and lie along the northwest border of the large area of monzonite, and near or on the contact of the porphyrites and Mount Roberts formation with the monzonite, granodiorite or granite porphyry. The South belt is underlain mainly by the porphyrites and sediments of Carboniferous age.

In the North belt, the ore deposits occur (a) in fissure veins with or without replacement of the country rock; (b) as lodes in zones of fissuring or shearing, the ore minerals forming a network of veinlets impregnating or replacing in whole or in part the intervening masses of country rock; (c) in irregular impregnations in the country rock. The most important ore bodies found so far have occurred as

indicated under (a) and (b). On the basis of mineral content, the ores may be classified as follows:—

1. Massive pyrrhotite and chalcopyrite ores with some pyrite, occasionally a little arsenopyrite and more rarely magnetite and molybdenite. Galena and blende have been found in a couple of instances. Free gold occurs, but is rarely visible though the proportion runs from 10 to 50 per cent. of the total gold content.

2. Massive coarse grained pyrrhotite with but little copper and gold.

3. Pyrite and marcasite with arsenopyrite in veins with possibly some galena and blende. This type is more characteristic of the South belt, and silver may form an important part of the values.

4. Arsenopyrite, pyrrhotite, pyrite, molybdenite, a little chalcopyrite, bismuthinite, and free gold, as impregnations particularly in and around pegmatitic and aplitic dykes of alkali syenite.

5. Gold bearing quartz veins.

*Gangue.*

The gangue is chiefly more or less altered country rock with some quartz and locally a little calcite. The country rock may be altered to quartz associated with secondary biotite in bands. Hornblende and chlorite are extensively developed in places. Muscovite, tourmaline, garnet, wollastonite and epidote also occur, and zeolites, chiefly anthophyllite and chabazite, are frequently found.

*Ore.*

The typical ore consists of more or less altered rock matter with reticulating veins and irregular masses of pyrrhotite, and varying amounts of chalcopyrite with perhaps a little quartz, the sulphides forming from 50 to 65 per cent. of the mass. There are all transitions from the solid sulphides forming massive shoots of ore on the one hand to rock matter or gangue on the other with little apparent mineralization. In cases, however, lightly mineralized gangue may carry high gold values.

The values are largely gold with some copper and a little silver, The gold values do not appear to be dependent on the presence of any one mineral, though in many cases ore rich in chalcopyrite is rich in gold. The pyrrhotite, though gold bearing in some instances, is as a rule very

low grade. An average analysis of the ore from the large producers gives—gold 0·5 oz. per ton, silver 0·3 oz. per ton, copper 0·9 per cent, iron 22 per cent, silica 37 per cent, sulphur 10·8 per cent, lime 4·2 per cent, alumina 14·9 per cent. The ore from near the surface yielded the higher values, but the proportion of free gold does not appear to decrease with depth and high grade ore bodies are still encountered at the lowest developed levels.

Oxidation extends downwards only a few feet from the surface. Secondary enrichment is a minor feature but is found at several points well below the zone of weathering.

*Lodes.*

The chief lodes or veins have a general easterly trend and northerly dip with an associated fault system trending north and south. The LeRoi-Centre Star main and south lodes and the Josie lode strike about N. 60° E. The LeRoi north vein, the War Eagle vein, and the Centre Star north veins strike N. 70° W., and appear to be offshoots of the main lodes. The dips are to the north ranging from 60° to 70° with local flattenings.

The main LeRoi-Centre Star lode is at least 4,000 feet (1,219 m.) long, with a thickness varying from a mere crack to over 130 feet (39·5 m.) The maximum thickness cannot in many instances be determined owing to the lack of sharply defined walls. Between ore shoots it is sometimes very difficult to trace the lode, particularly where the continuity is broken by faults and dykes.

*Ore Shoots.*

The ore shoots vary greatly in size and shape, lenticular bodies being the more common. Some are very irregular at one termination especially when forming against a dyke or fault. In such cases the shoot either develops an enormously increased thickness or an L-shaped body is formed by the ore turning sharply and following the plane of the fault or dyke. The pitch varies from vertical to a pronounced easterly or westerly direction dependent upon purely local conditions. In size the shoots vary from a foot (30 cm.) to 130 feet (39·5 m.) in thickness and from 50 to 500 feet (15 to 152 m.) in length. One of

the largest shoots was stoped for 590 feet (152 m.) vertically and averaged 150 feet (32 m.) in length and 56 feet (17 m.) in thickness.

The higher grades of ore are often confined to certain bands in the shoot parallel to the trend of the lode. They either occur in the body of the shoot or on the hanging or foot wall sides. These bands may also change their relative positions suddenly and follow other though parallel planes in the shoots.

The pay ore is sometimes bounded by a fissure or fault plane. More often, however, there is no sharply defined wall, but a transition, usually rapid, from commercial ore to "waste" or nearly barren rock.

The positions of shoots are usually along contacts between the lode and fault planes with impervious walls or dykes. In the case of the dykes the shoots usually form on the under side. When the mashing or shearing of the rock is such that the metal bearing solutions are restricted within zones of reasonable width, other things being equal, the conditions are favorable for the formation of productive ore shoots. The importance of the shoot is ofttimes accentuated by the development of a system of cross fractures emanating from the wall rock.

In the LeRoi, shoots have been found along the contact of the augite porphyrite series and the coarse monzonite and diorite porphyry.

*Origin.*

Ore deposition began subsequent to the extensive intrusions of alkali syenite and continued up to the period of injection of the last system of dykes. It is thought probable that the deposits are closely related to the alkali syenite.

The deposits were formed through the agency of ascending aqueous mineral-bearing solutions of high temperature which gradually replaced the primary minerals of the country rocks particularly the feldspar.

Certain minerals in small quantities, such as garnet, wollastonite, epidote, amphibole, pyroxene and magnetite suggest an approach to the conditions under which contact metamorphic deposits are formed. Other minerals are characteristic of hydrothermal action such as tourmaline, muscovite, chlorite and zeolites. The paragenesis of the minerals has not been worked out, but pyrrhotite is cut

by veinlets of chalcopyrite though in many cases the two minerals appear to have been contemporaneous.

The values so far have not greatly decreased with depth, though this is not apparent in the production since more lower grade ore can now be mined than formerly because of reduced smelting charges. The evidence though not conclusive, is strongly in favour of almost the entire deposition being due to ascending solutions, though possibly at two or more periods. In the first period, the dyking and faulting phenomena accompanying the formation of the lodes formed barriers which afforded favourable conditions for the precipitation of copper and gold. A favourable area for deposition appears to be the underside of dykes. In the second period, ascending solutions of different composition may have deposited new minerals in the ores or concentrated at successively higher levels, the values of the ore minerals formerly deposited.

If a zone of true secondary enrichment ever existed, it was swept away during the heavy erosion accomplished by the Cordilleran ice sheets.

The success that has attended the vigorous development policy of the operating companies, gives no indication that the productivity of the lodes is near the end, nor even on the wane, but on the other hand, gives every encouragement to the view that ore bodies will be found at much greater depths than the levels now being exploited.

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## GEOLOGY OF THE REGION BETWEEN CASTLEGAR AND REVELSTOKE.

### THE ARROW LAKES.

Between West Robson and Arrowhead there are two pronounced expansions of the Columbia river known as Upper and Lower Arrow lakes, which with the river connections have a total length of about 107 miles (172 km.). The junction of Lower Arrow lake and the Columbia river is about 10 miles (16 km.) west of Castlegar. The lake, whose shape is that of a slightly bent bow with the convex side to the west, has a length of about 51 miles (82 km.) with an average width of about one mile (1·6 km.) tapering at both ends. The low water level is about

1,380 feet (420 m.) above sea level and a sounding taken about the central part of the lake gives a depth of 537 feet (163 m.). The river connection between the lakes is about 20 miles (32 km.) long, the lower 11 miles (17 km.) following a valley parallel to Upper Arrow lake, while the upper nine miles (14 km.) lies in a transverse valley which cuts across the axis of a mountain ranges trending northwest.

Upper Arrow lake has a northerly trend and is about 36 miles (58 km.) long with a prominent northeast arm 10 miles (16 km.) long. The lake has an average width of two miles (3·2 km.) and the low water level is 1,384 feet (422 m.) above the sea level. Two soundings one 12 miles (19 km.) north of the lower end of the lake, and another four miles (6·4 km.) north of Halcyon, give 490 and 720+ feet (149 and 219+m.) respectively.

From Arrowhead to Revelstoke Columbia river trends N. 35° W. and is a navigable stream for shallow draught steamers. The river meanders with blind channels through flat bottom land from 1 to 1·5 miles (1·6 to 2·4 km.) wide. For six miles (9·6 km.) above Arrowhead low flats border both sides of the river. Above that point they lie alternately on one side of the river or the other. Below Revelstoke the river closely hugs the rocky western shore. The valley is continuously bordered on both sides by mountain ranges and is in that respect analogous to the valleys of the lakes to the south.

The shore line of these lakes is steep with numerous rocky bluffs; occasionally portions are fringed by narrow beaches and locally by more widely expanded delta deposits at the mouths of entering streams. The bordering mountain ranges are lofty and rugged and attain elevations from 6,000 feet (1,828 m.) to over 8,000 feet (2,438 m.) above sea level. Their axial lines are narrow and lie from four to six miles (6·4 to 9·6 km.) inland from the valley trench. In places the steeper slopes are scarred by landslides, the most recent one having occurred early in 1903 on the north side of the valley of the northeast arm a little to the east of Arrowhead.

The usual types of fiord topography are in evidence throughout the length of the two lakes, illustrating varied examples of cliff walls, truncated spurs, hanging and V-shaped lateral valleys, terraces, alluvial cones and fans and continuous evidence of heavy glacial scoring and undercutting.

The river connecting the two lakes is rather more than a mile (1·6 km.) in width, bordered by flat bottom lands and low terraces. This portion of the valley must represent an ancient and deep hollow filled in by glacial drift and later deposits. At present considerable sedimentation is being effected by the material carried down by the tributary streams.

## GENERAL GEOLOGY [8].

The geology of the valley sides and neighbouring mountain ranges has not been worked up in any detail and at present only permits of a very generalized description. From Castlegar to a point about south of Saddle peak the valley is eroded in rocks of two batholithic intrusions, the earlier being the Nelson granodiorite of Jurassic (?) age, and the later the Rossland alkali granitic rocks tentatively referred to early Tertiary. The former extends from Castlegar to near Deer Park and then again from a point three miles (4·8 km.) south of the Needles to the bend in the Columbia river. The latter extends from Shields to a point three miles (4·8 km.) south of the Needles and occupies for the most part both shores of the lake. Of irregular lenticular form the batholith is 38 miles (61 km.) in length along its north axis with a maximum width of 17 miles (27 km.). Lying in these batholiths are a few remnants of the Rossland group with some associated limestone developed along the lower portions of Lower Arrow lake particularly in the vicinity of Deer Park.

South of Saddle peak a band of schists and gneisses presumably of the Shuswap series crosses the valley with a trend a little west of north.

Little is definitely known of the shores of Upper Arrow lake as far as Halcyon. The rocks are schists, gneisses, slates and crystalline limestones intruded by dykes, sills and stocks of late granites, etc. They may be referred to the Shuswap and Selkirk series together with highly metamorphosed phases of the Slocan series. They are much disturbed and faulted requiring detailed work to elucidate their structure.

From Halcyon to Arrowhead the Shuswap terrane is developed except at Thumb bay where the continuity is broken by an intrusion of granite some five miles (8 km.) wide which crosses the lake with a northwest trend.

From Arrowhead to Revelstoke the Shuswap series consists largely of orthogneisses with minor developments of mica schists, quartzite and crystalline limestone intruded by later dykes of pegmatite and aplite. The rocks are much disturbed and faulted as shown by discordant strikes and dips. In places the strike parallels the valley, in other cases it lies at right angles to it.

## ANNOTATED GUIDE.

**Nakusp**—The upper terraces behind the town represent in part the delta deposits of Kuskanax and Nakusp creeks. The low delta face of the former creek has extended well into the lake. Ten miles (16 km.) up the Kuskanax are a series of hot springs, as yet but little known, though readily accessible by trail.

**St. Leon**—St. Leon marks the junction of two streams in modified V-shaped valleys. The upper delta terraces are about 200 feet (60 m.) above the lake. About one mile (16 km.) inland hot springs occur.

**Halcyon**—At Halcyon are the most noted of the hot springs which appear at intervals along the east side of Upper Arrow lake. There are two adjoining springs about 1,700 feet (518 m.) inland and 400 feet (122 m.) above the lake. The water flows from two orifices in biotite gneiss at a temperature of 124° F. (68·8° C.) with an estimated flow of 300 gallons per minute. An analysis made by J. F. King in the laboratory of the City Analyst, Edinburgh, March 3, 1898, showed the water to contain the following ingredients expressed in parts:

| | |
|---|---|
| Chlorine | 8·14 |
| Sulphuric acid | 363·43 |
| Silica | 74·29 |
| Lime | 84·57 |
| Alkalies as soda | 5·71 |
| Magnesia | 232· |
| Lithia | 0·86 |
| Sulphuretted hydrogen | 32· |

Looking west from Halcyon across the lake a range is to be seen in which are many lofty peaks with glaciers and snowfields. This range extends to near Revelstoke where

the culminating peak Mount Begbie has an elevation of 8,946 feet (2,726 m.) above the sea.

**Arrowhead**—On approching Arrowhead a good view is obtained of the peaks and snow fields at the head of the northeast arm, and of the scar left by the landside of 1903. On the face of the hill directly behind the town two heavy sills of granite are intruded in the Shuswap schists. The upper sill has a marked vertical jointing.

**Wigwam**—At Wigwam rock terraces mark the floor of the more ancient valley. The Akolkolex river entering from the east, affords a striking example of a hanging valley.

**Revelstoke**—The city is on the main line of the Canadian Pacific railway, situated at the junction of the Columbia and Illecillewaet rivers.

## SLOCAN SILVER-LEAD DISTRICT.

### ANNOTATED GUIDE.

(South Slocan to New Denver).

Miles and Kilometres.

**South Slocan**—Alt. 1637 ft. (499 m.) is 12 miles (19 km.) west of Nelson and is the junction point of the railway branch running north to Slocan lake and the silver-lead and zinc mines of the Slocan district. The railway closely follows the Slocan river which in places has cut down to bed rock though along most of its course it flows in a channel eroded in the heavy deposits of stratified sand, sandy clay and gravels which have filled the rather broad U-shaped valley to a considerable depth. The bed rock is mainly the granodiorite and associated types of the Nelson batholith. Between Koch and Winlaw there is an area of gneisses and schists lying in the granodiorite which are referred to the Shuswap series.

43 miles 69 km. **Slocan City**—Alt. 1,777 ft. (541 m.) lies at the foot of the lake of the same name and is the point of departure to the silver mines lying at the east in the granitic rocks. The ores are mainly dry, that is the silver values usually

Miles and Kilometres.

predominate over the lead and the gangue is essentially quartz. Slocan lake is of the same type as Kootenay and the Arrow lakes. The several features, however, of mountain peak, glacier and delta give it a beauty peculiarly its own and by many is considered the most beautiful lake from a scenic view point in southern British Columbia.

The lower half of the lake is eroded in the granitic rocks of the Nelson batholith, the main part of the upper half lies on the contact of those rocks with those of the Slocan slates. The form of the lake is bow-like with the convex side to the east. It has a length of about 25 miles (40 km.) and an average width of one mile (1·6 km.) with a low water elevation of 1,761 feet (537 m). Two soundings, one near the south end and one opposite Roseberry give respective depths of 925 and 765 feet (282 and 233 m.).

62 miles 100 km. **Silverton** is situated on the delta of Four-mile creek. It is the distributing point for several silver-lead mines, the more important being the Standard, Hewitt and Van Roi, and the L-H gold mine.

65 miles 104 km. **New Denver** is situated on the delta of Carpenter creek and is within easy distance of the majority of the most important silver-lead and zinc mines of the Slocan district, the principal centres being Silverton, Sandon, McGuigan and Whitewater.

## Silver–Lead and Zinc Deposits.

The district in which productive ore bodies have been found comprises the Ainsworth, Slocan and Slocan City Mining divisions. The district lies within the Selkirk system of the Cordillera and is characterized by strong relief showing all the more prominent features of alpine topography. The maximum vertical range between mountain peak and valley is over 6000 feet (1828 m). Most of the veins occur well up on the mountain slopes and consequently the mines are invariably developed by series of tunnels.

Although the lead deposits in the vicinity of Ainsworth on Kootenay lake were being worked in the later 80's, it was not until 1891 that the richer and more important ore deposits were staked inland from Kootenay lake and further to the west. In the early years the transportation difficulties were great, so that it was not until 1895 that important shipments were made. The total production from 1895 to the end of 1911 in round numbers amounts to 795,000 tons of ore, containing 30,875,000 ounces of silver, 2890 ounces of gold, 269,460,000 pounds of lead with a total value of nearly $29,000,000. The zinc returns from 1907 to 1911 are valued at nearly $1,000,000.

**General Geology**—The deposits occur in the granitic works of the Nelson batholith but particularly in the sedimentary rocks of the Slocan series (Carboniferous?). The granitic rocks range from true granite to quartz diorite. They are almost prevailingly of a light grey colour and the texture ranges from medium to coarse grain. Outside of the main area of the batholith the rocks appear in the sedimentaries as dykes, stocks and irregular masses.

The Slocan series consists of interbedded argillaceous quartzites and limestones, and slates or argillites which are more or less carbonaceous. They form an undoubtedly thick series, but the folding, faulting and lithological similarity prevent any section being made that would give even an approximation to the actual thickness. The series is extensively dyked by quartz porphyry and lamprophyres which are older than the fissure system containing the ore bodies.

**Veins**—The veins are nearly all of the fissure type and are much more numerous in the Slocan series. There they almost invariably cut across the strike of the formation, if they coincide in strike they cut across the dip and terminate usually by either turning suddenly and following a bedding plane or by feathering out in the broader bands of the softer slates. The veins vary in length from a few hundred feet to over 4000 feet (1219 m.) and in thickness from a few inches (cm) to over 50 feet (18 m.). In exceptional cases the vein may attain a thickness of 150 feet (45 m).

The widest portions of the veins are generally filled with crushed and broken country rock with but relatively small amounts of the gangue minerals. In certain definite areas the fissures form a widely parallel system; the dips

range from 40 to 80 degrees and as a rule are well over 50 degrees.

**Ore shoots**—The ore shoots are composite in character and consist of widely parallel bands, lenses and masses of galena and zinc blende alternating with siderite and to a less extent with quartz and calcite. As a rule the high grade ore favours the hanging wall side of the vein, though this is not invariably so. The shoots also favour the carbonaceous slates rather than the quartzites, porphyry stocks or dykes, but the reverse again holds in a few instances. Another favourable factor in the formation of shoots is the cross fissures which pass across the vein from either the foot or hanging wall side. These appear to have formed accessible channels for the metal bearing solutions. The shoots vary in length from 15 or 20 feet (4·5 or 6 m.) to 400 feet (122 m.) or over, and in width from a few inches (cm) to 40 feet (12 m.).

The vertical component varies from 10 feet (3 m.) or so to 500 and 600 feet (152 to 182 m.) in the larger bodies. In many cases with, however, numerous exceptions, the shoot bears a relation to the topography of the country and pitches out of the hill. With depth the ore gets poorer and passes into slightly mineralized gangue and crushed rock.

**Mineral composition**—The chief metallic minerals are galena and zinc blende. With freibergite as the important silver bearing ore, ruby and native silver and argentite are found in many of the deposits developed along fractures in the more massive ore. Chalcopyrite and pyrite are almost invariably present, the former in small amount, the latter in increasing quantity as the lead content diminishes. The zone of weathering is very shallow but originally contained carbonates of lead, zinc and copper and in one instance linarite, a sulphate of lead and copper.

The gangue is composed of siderite, calcite and quartz in varying proportions, the quartz content usually increasing with depth.

At present the metallic contents of the ores mined range from 7 per cent of lead and 20 ounces of silver to the ton to one carrying from 50 to 75 per cent of lead and from 80 to 175 ounces of silver to the ton. In some mines there is a little gold which ranges in value from $1.00 to $7.00 to the ton.

**Origin**—No definite law holds with regard to the order of the formation of the several minerals. In many instances however, siderite was formed first, followed by zinc blende which replaced a portion of the siderite. Galena succeeded the blende, and freibergite followed, filling in fractures in the galena and to a certain extent in the blende.

The ore appears in great part to be primary and to have been introduced by ascending solutions which deposited their mineral content in the wider portions of the veins at favourable horizons, where the action was aided by decrease of pressure, lower temperature and by the reducing action of the carbon in the crushed rock which forms an important percentage of the vein filling.

The ore was probably derived from some horizon of the granitic rocks of the batholith which underlies the whole area and is perhaps closely connected with the basic lamprophyric dykes. In several instances it was noted that veins followed the same fissures as the dykes, in which cases the ore lay on and along the dyke.

Many of the ore shoots so far stoped have been comparatively shallow, but more recent development work has shown ore at greater depths, in one case 1,270 feet (387 m.) below the outcrop. The development of the last two years has encouraged the belief that the ore shoots are not merely surface deposits but that they will be found to have a much greater vertical range than was formerly believed.

ANNOTATED GUIDE (Continued).

Miles and Kilometres.

69 m. 111 km. **Roseberry** is situated on the delta of Wilson creek at an elevation of 1,795 feet (547 m.) above the sea. Just north of the station the railway crosses an apophysis of the granodiorite intruded in the Slocan slates. Slocan lake terminates north of Hills, but the valley trench continues through to Nakusp, the railway following closely the contact between the Slocan series and the granodiorite. About a mile (1·6 km.) north of Hills the abandoned valley of the creek draining Summit lake is exposed, the present creek flowing in a valley a little further to the west.

Miles and Kilometres.

At the summit the elevation is 2,500 feet (762 m.), and from there the railway descends to Nakusp passing across the upper terraces and delta deposits of Kuskanax and Nakusp creeks and finally arriving on the present delta by means of a long switch back.

97 m.
156 km. **Nakusp.**

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# THE SIMILKAMEEN DISTRICT.

## Midway to Spence's Bridge.

BY

CHARLES CAMSELL.

## INTRODUCTION.

The Similkameen excursion leaves the route of Excursion C2 at Midway, and after proceeding westward along the valley of Similkameen river turns northward at Tulameen towards Nicola river, and at Spence's Bridge, where this stream enters Thompson river, it again joins the route of Excursion C2.

This route of this excursion lies almost entirely in the Interior Plateau region of British Columbia, and an excellent opportunity is afforded of viewing what is one of the main physiographic features of the province of British Columbia. The characteristic features of mature topographic outline in this region are believed to have been produced by sub-aerial erosion acting throughout Eocene times, though they have been somewhat modified by subsequent events which include regional elevation, vulcanism and glaciation. The region is underlain by sedimentary and volcanic rocks ranging in age from Carboniferous to Miocene, the older of which have been intruded by batholithic igneous rocks.

The chief points of scientific and economic interest which it is the object of this excursion to visit are: the gold bearing arsenopyrite deposits of the Nickel Plate mine,

and the roof contact of a granodiorite batholith, at Hedley; Oligocene lake basins at Princeton, and Nicola; the platinum and diamond bearing peridotite, at Tulameen.

## ANNOTATED GUIDE.

### MIDWAY TO HEDLEY.

| Miles and Kilometres. | |
|---|---|
| 0 m.<br>0 km. | **Midway**—Alt. 1,908 ft. (581·5 m.). Midway is a small town of a few hundred inhabitants, situated in the drift-filled valley of Kettle river at the mouth of Boundary creek. It lies in an area of Oligocene rocks, consisting of somewhat disturbed volcanic flows and tuffs, interbedded with sandstones and shales. Associated with them are some thin seams amd lenses of lignite.<br>For three miles (4·8 m.) beyond Midway the Great Northern railway runs westward along the valleys of Kettle river and Myers creek through an open, wooded, park-like country, and after passing through a tunnel enters a narrow gorge, cut in massive Oligicene lavas. |
| 9 m.<br>14·5 km. | **Bergen**—Alt. 2,409 ft. (733·2 m.). Beyond Bergen the valley broadens into open, grassy meadows, partly under cultivation, and in the railway cuttings are exposures of Oligocene slates and sandstones which dip eastward and form the western border of the basin through which the railway has run from Midway. These rocks rest unconformably on much disturbed and compressed Palæozoic schists, which are considered to be of Carboniferous age and correlated with the Cache Creek group. They extend for two and a half miles along the railway, to Mile post 79, where they give place to a body of Jurassic granodiorite which is intrusive into them. |
| 14 m.<br>22·5 km. | **Myncaster**—Alt. 2,732 ft. (832·4 m.). Palæozoic schists again appear at Myncaster, replacing the granodiorite. From this point the railway turns abruptly to the north and after series of sharp curves crosses from the valley of Myers creek to that of Rock creek. |

Miles and Kilometres.

It follows the south slope of Rock creek valley westward through a small area of Tertiary volcanic rocks and on leaving it to ascend the valley of Baker creek, it again enters Palæozoic rocks, exposures of which can be seen in the railway cuts.

26 m. 41·8 km. **Bridesville**—Alt. 3,407 ft. (1,038 m.). Near the head of Baker creek the railway crosses the International Boundary line at a point two miles east of Molson, and from this pont westward to Chopaka on the Similkameen river, the route lies in the State of Washington.

31 m. 49·8 km. **Molson**—Alt. 3,705 ft. (1,128 m.). Molson is situated on the divide between Kettle river and Okanagan river, in a region characterized by rounded, grassy hills, on which there are few exposures of the solid rocks. From here an imperfect view can be obtained to the north and west of a part of the great Interior Palateau of British Columbia, noteworthy features of which are the evenness of its skyline, and the maturity of its topographic forms. From Molson a descent of 2,764 feet (825 m.) is made down a grassy open slope to the bottom of Okanagan valley to Oroville, which is distant 25 miles (40·2 km.).

42 m. 67·6 km. **Circle**—Alt. 2,571 ft. (783 m.). The old Palæozoic rocks, through which the railway has run from Bridesville, are overlapped at Circle by Tertiary rocks consisting of sandstones, shales, and lavas, which cover the slope of Okanagan valley virtually to Oroville.

56 m. 90 km. **Oroville**—Alt. 941 ft. (286·8 m.). Oroville, a town of about one thousand inhabitants, is situated in Okanagan valley at the south end of Osoyoos lake and at the entrance of the Similkameen river. Geologically it lies in one of the interior lake basins of Oligocene age, the rocks of which consist of conglomerates, sandstones, and shale associated with some volcanic flows. Okanagan valley, which has been cut through this basin, is one of the main north and south valleys of the Cordilleran region, and during the Glacial period was occupied by the southward

Miles and Kilometres.

moving Okanagan glacier. Evidences of its occupation by this glacier are still preserved in the shape of the valley, in numerous glacial striae, and accumulations of glacial material. The width and climate of the valley make it excellent for fruit growing which is the principal industry of the district.

The railway crosses Okanagan valley at right angles at Oroville and enters the valley of Similkameen river, which it follows as far as the town of Princeton, a distance of 80 miles (128·7 km.).

The Similkameen river belongs to the Columbia drainage system. It rises on the eastern slope of the western ranges of the Cascade mountain system, and, flowing at first in a northerly direction and afterwards westward, cuts at right angles through the axis of the Okanagan range in the neighbourhood of Keremeos. Its valley is antecedent to the formation of the Okanagan range, which is believed to have been elevated in Pliocene times. During the Glacial period it was occupied by a great valley glacier moving south-eastward to join the Okanagan glacier. The truncated spurs and characteristic U-shape, which it has near the International Boundary line, are evidences of that occupation.

For 12 miles (19·3 km.) above Oroville the Similkameen river has an easterly trend, and as this direction is approximately at right angles to the movement of glacial ice, its valley has not been greatly modified and is still narrow and in places canyon-like. A bed of hard Tertiary conglomerate makes a barrier across the river and causes a fall of 23 feet (7 m.) at which 500 electrical horse power is developed to supply neighbouring towns.

67 m. 106 km. **Nighthawk**—Alt. 1,130 ft. (344 m.). The Tertiary rocks of this part of the valley rest directly on Palæozoic schists and limestones of Carboniferous age, and wherever they are exposed some prospecting and mining development has been carried out principally on gold

The trough-shaped glaciated valley of Similkameen river.


Geological Survey, Canada.

Route map between **Midway** and **Princeton**

Miles: 10 5 0 10 20

Kilometres: 10 5 0 10 20 30

Miles and Kilometres.

ores. The Palæozoic rocks are intruded by granodiorite, probably Tertiary in age, the contact crossing the valley 3 miles (4·83 km.) east of Nighthawk.

77 m. 124 km. **Chopaka**—Alt. 1,150 ft. (350·5 m.). Beyond Nighthawk, the railway enters a broad glaciated valley, running almost north and south, and turning sharply to the north within a few miles crosses the International Boundary line into Canada at Chopaka. From here northward to Keremeos the river and railway follow the eastern foot of the Okanagan mountains, the extreme eastern range of the Cascade system, which rises abruptly from the valley bottom to an elevation of 8,000 feet (2,438 m.) above sea level. Crossing the Similkameen river 4 miles (6·4 km.) north of the boundary line, where the Palæozoic rocks are again in contact with the granodiorite, the railway keeps the eastern side of the stream for several miles. These Palæozoic rocks form both sides of the valley almost up to Hedley, except where they are capped by almost horizontally Tertiary volcanic rocks on the east side of the valley below Keremeos.

94 m. 151·2 km. **Keremeos**—Alt 1,330 ft. (405·4 m.). Keremeos, situated at the mouth of Keremeos creek, and formerly one of the oldest Hudsons Bay Company's fur trading posts in the district, is now the centre of a good fru t farming country. Gold-copper deposits in the mountains to the north make it important from a mining point of view.

Above Keremeos Similkameen river cuts a broad but steep-sided valley through the axis of the Okanagan range, which is here built out of Palæozoic sediments and volcanics. A series of talus slopes, remarkable for their great size and length are developed on the north side of the valley.

101 m. 162·5 km. **Ashnola**—Alt. 1,420 ft. (432·2 m.). Seven miles (11·26 km.) above Keremeos Ashnola river, a swift turbulent stream, draining the high mountainous region about the International Boundary line, enters from the south. The

Miles and Kilometres.

railway is here on the south side of the river, but soon crosses back to the north, and after passing Bradshaw, reaches the town of Hedley at the mouth of Twentymile creek.

107 m. 172 km. **Bradshaw.**—

112 m. 165·7 km. **Hedley**—Alt. 1,650 ft. (502 m.).

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## GEOLOGY OF THE REGION ABOUT HEDLEY.

### GENERAL DESCRIPTION.

**Physiography.** The Hedley district [**2,**] lies in the Interior Plateau region of southern British Columbia on the western flank of the Okanagan range of mountains, which is an elongation of the Cascade Mountain system. The plateau occupies the whole of the central part of British Columbia, and is characterized in its upper levels by wide flaring valleys separating broadly rounded or almost flat topped summits which merge together in an almost level sky line, having an elevation in this part of about 6,000 feet (1,827 m.) above sea level. Into the surface of the plateau the master streams have entrenched themselves to a depth of 2,000 feet (609 m.) or more, and now occupy steep sided valleys, which have been modified by valley glaciation to produce the characteristic U-shape typical of Similkameen valley.

To the long erosion period following the Laramide uplift is due the uniformity of level of the upper surfaces of the region, while the entrenchment of the streams in the deep valleys is attributed to the period following the uplift of the Interior Plateau and Cascade mountains in late Pliocene times. A topographic break, occurring about the 4,000 foot (1,219 m.) contour in the grade of the small streams and projecting spurs entering the Similkameen valley, is used as evidence in support of the idea that the degree of uplift in this region during Pliocene times was at least 2,500 feet (762 m.).

The effects of both continental and valley glaciation are apparent throughout the region. On the upper levels continental glaciation has accentuated the maturity of

relief by depositing a mantle of drift over the surface of the region while in the main valleys the effect of valley glaciation is evident in deepening and in transforming what must have been a V-shape into a well marked U-shape.

Valley glaciation has probably been, in part at least, the cause of the formation of the hanging valleys, which are so marked a feature of the Hedley district. Unequal deepening of the main and tributary valleys by streams revived by uplift may, however, also have been partly responsible for the hanging valleys.

The location of the valleys of the smaller streams along their present courses has been dependent, in many cases, upon the structure of the underlying rocks, and they are consequently subsequent streams. It is not so clear what were the causes determining the course and direction of Similkameen river. It is inferred, however, from the way in which that stream cuts across the axis of the Okanagan range, that it must have occupied its present bed prior to the Pliocene uplift, and consequently in relation to the Okanagan range, it is an antecedent stream.

**Geology.** The oldest rocks of the Hedley district are of Carboniferous age and consist of massive limestones, thin bedded quartzites and argillites, and a great thickness of volcanic tuffs. They have been folded by pressure exerted in an east and west direction, and in consequence dip towards the west at angles varying from 15 to 90 degrees. They are traversed by two sets of faults which strike roughly northeast and northwest.

Plutonic igneous rocks have been intruded through the sedimentary rocks in the following order:—(1) diorite and gabbro, (2) granodiorite. These igneous rocks have been accompanied by a great number of apophyses, and followed by lamprophyres, and other dyke rocks.

Over all is a thin mantle of glacial and post-glacial deposits.

The following is a table of formations:—

Quaternary—Stream deposits and glacial drift.

Tertiary?—Granodiorite.

Mesozoic?—Diorite and gabbro.

Carboniferous?—Limestone, quartzite, argillite, and volcanic materials.

The ore deposits of the district are of contact metamorphic origin and of a type unique among North American deposits. They contain gold, the only valuable con-

stituent, associated with arsenopyrite in a gangue of quartz, calcite, epidote, garnet, diopside, and other lime-silicate minerals. The ore bodies are of irregular shape and without clearly defined boundaries.

They occur in altered silicified limestone beds of Carboniferous age at the contact of intrusive sheets and dykes of a light coloured gabbro, which appear to have emanated from a central stock of the same material. They appear to be genetically connected with the gabbro, and to have been formed at the time of intrusion of that rock into the limestone. The ore bodies being worked contain gold to the value of about $11.00 to the ton, and the mines are the biggest producers of gold alone of any mines in British Columbia.

The deposits were discovered in 1894 and in 1904, actual milling of the ores began and has since continued without interruption.

PARTICULAR DESCRIPTIONS.

The chief points of geological interest at Hedley, which it is the object of the excursion to visit are the following:

(1) Roof contact of a granodiorite batholith, exposed near the stamp mill of the Hedley Gold Mining company.

(2) The Interior Plateau, to be seen from the top of Nickel Plate mountain.

(3) The Nickel Plate mine.

**Roof contact of Granodiorite batholith.**

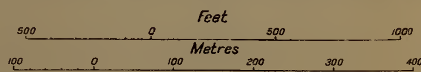
An excellent section, showing the roof contact of a granodiorite batholith with tilted Carboniferous sedimentary strata, is exposed on the northern side of Similkameen valley east of the town of Hedley, and can be seen in a large way from the railway station.

The contact illustrates a case of differentiation in a slowly cooling, igneous magma by the rising of the lighter constituents, quartz and feldspar, to the upper surface of the batholith, and the filling of pockets and fractures in the sedimentary roof by these lighter constituents, where they form aplite and quartz porphyry dykes and even quartz veins.

It also illustrates in certain features the theory of batholithic intrusion by stoping; there is little structural disturbance in the intruded rocks; the contact line in


Geological Survey, Canada

Natural Section of Nickel Plate Mountain showing the roof contact of the granodiorite batholith



detail is angular; and the batholith contains many inclusions of the intruded rocks, some of them recrystallized.

The base of the mountain, as seen from the railway station, is composed of massive granodiorite for the first 500 feet (152 m.) above the valley flat. Above are steeper cliffs of interbanded sediments and intrusive porphyrite sheets dipping to the west at about 30 degrees. The contact is approximately horizontal, and the intruded rocks are truncated by the batholith with little or no structural disturbance.

The granodiorite is a light-coloured, medium-grained rock consisting of feldspar, quartz, biotite and hornblende. It contains many dark inclusions and segregations varying from 2 to 10 inches (5 to 25 centimetres) in diameter. Some of these are angular and some are oval. The angular ones are, without doubt, inclusions of either limestone or quartzite. The rounded ones are recrystallizations and may represent fragments stoped from the roof and recrystallized by the heat of the magma.

The accompanying section illustrates the nature of the contact, and it is noticeable that the acid contact zone is thick in pockets in the roof of the batholith, while it is comparatively thin or almost absent where a corner projecting down into the batholith forms the roof.

On approaching the contact from below at one of these pockets and at a distance of about 40 feet (12·2 m.) below the roof, the granodiorite has its normal characteristics. At 25 feet (7·6 m.) from the contact there is a noticeable change due to the partial elimination of the basic minerals, and at 15 feet (4·5 m.) away these minerals are almost entirely absent, and the rock becomes a fine-grained pink variety made up largely of quartz, orthoclase, a little plagioclase, and small flakes of biotite. A tendency to porphyritic structure is also developed. Within three feet (·9 m.) of the contact the change is most marked, and the rock is noticeably more silicious. The porphyritic structure is also well developed, the rock becoming a quartz porphyry traversed by many small veins of guartz. The thin section shows this rock to consist of phenocrysts of orthoclase and quartz, sometimes exhibiting a micrographic intergrowth, in a fine-grained ground mass of the same minerals also intergrown together in the same structure. At the actual contact is about two inches (5 cm.) of perfectly white, fine-grained, soft rock, now so decomposed as to

be indeterminable. The contact is a sharp, clean-cut line showing no blending of the two rocks, and above is a coarse-grained crystalline limestone.

Apophyses from the granodiorite into the roof are of the same character as the contact zone. They are very silicious quartz porphyries, which, a few hundred feet from the contact, become quartz veins.

**Interior Plateau.**

From the upper terminal of the Hedley Gold Mining Company's gravity tramway, at an elevation of 5,400 feet (1,646 m.) above sea level, an excellent view of the Interior Plateau is obtained looking west. The plateau seen from this point is merely a bay at the southern end, lying between the Okanagan range on the east and the Hozameen range on the west, with the Princeton depression in its central part. The main extent of the plateau is towards the north, in which direction it stretches, with a width of about 100 miles (160 km.) far into the northern interior of British Columbia.

Considerable doubt still exists relative to the history and development of the characteristic features of the Interior Plateau region. A maturity of relief and an evenness of sky line, probably not amounting to actual peneplanation, are believed to have been produced by subaerial erosion acting throughout Eocene times. To some extent, at least, these features have been preserved in the present topography of the region; and although much of the region has undergone considerable disturbance by mountain building forces and vulcanism, in the succeeding periods, local irregularities of the surface produced at such periods were again reduced by erosion in the quiescent periods following them, especially in early Pliocene. Since, therefore, the Interior Plateau region has been subject to erosive action throughout the whole of Tertiary times, its present physiographic characteristics should be considered as the cumulative result of that long period of time, rather than of any single period of the Tertiary. There is no doubt that at a time immediately preceding the Pliocene uplift the vertical relief in the region must have been fairly low and the maturity of form much more pronounced than at the present time. The Pliocene uplift is estimated to have elevated this region about 2,500 feet (762 m.) higher above sea-level than its pre-Pliocene level, and the deep trough-

General view of Interior Plateau region.

like valleys,—of which the Similkameen valley is a typical example—are the result of stream erosion following that uplift. These valleys have, however, since been modified by glaciation to their present U-shape. Glaciation has also, to some extent, been responsible for smoothing out the irregularities of the surface and reducing the summit levels of the region.

### Nickel Plate Mine.

The Nickel Plate mine is situated on the eastern slope of Nickel Plate mountain at an elevation of about 5,700 feet (1,737 m.) above sea level. The ore deposits in it are of contact metamorphic origin and occur at the contact of dykes and sheets of gabbro in limestones which have been altered by the gabbro. They are irregular in outline and have usually a well-defined boundary only on the side of the gabbro.

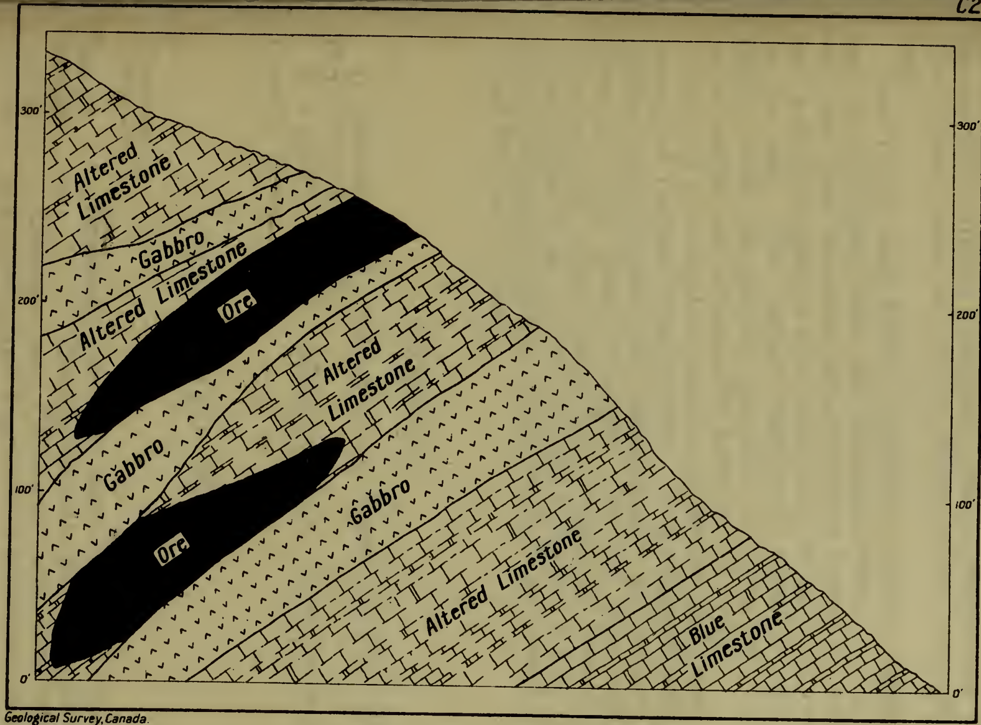
The gangue of the ore bodies contains minerals formed by the alteration of limestone, including garnet, epidote, diopside, amphibole, quartz, calcite, and axinite.

The principal ore mineral is arsenopyrite, with which occur chalcopyrite, pyrrhotite, zinc blende, pyrite, native gold, and sometimes tetradymite. These minerals are distributed through the gangue in crystallized individuals, or fill minute fractures in it. The valuable content of the ore is gold alone, which in that now being mined, averages about $11.00 to the ton.

These deposits afford an excellent illustration of contact metamorphism induced by the intrusion of igneous bodies into calcareous rocks, and show the resulting alteration of the original carbonates to silicates. They illustrate also the formation of ore bodies by the transfer of ore material from the igneous rock to the sedimentary, under such conditions of temperature and pressure, that the constituents introduced, and those originally present and recrystallized, are intergrown together as a result of contemporaneous crystallization.

In the association of gold with arsenopyrite in deposits of this origin the Nickel Plate ore deposits are unique and have no known counterpart on the continent. In the classification of ore deposits, they are therefore placed in a division by themselves, and are called the "Arsenopyrite type" of contact metamorphic deposits.

C2.




Section through the **Nickel Plate Mine.**
showing the relation of the ore bodies to the gabbro intrusives

### INDUSTRIAL NOTES.

At the present time the chief industry of Hedley is mining, and the activity of the district depends on the operation of the mines and the reduction works of the Hedley Gold Mining Company, and to prospecting and development work on mining claims in the surrounding region.

The Hedley Gold Mining Company employs about 60 men in the Nickel Plate and Sunnyside mines on the top of Nickel Plate mountain, and operates a system of electric and gravity tramways which carry the ore from the mines to the mill. The electric tramway is about a mile in length, while the gravity tramway is 10,000 feet (3,048 m.) in length, and drops nearly 4,000 feet (1,219 m).

The mill is situated at the town of Hedley and treats an average of 160 tons of ore per day. It is equipped with 40 stamps, two tube mills, and cyanide tanks, and is operated either by water power or steam. The ore being treated has an average value of about $11.00 to the ton from which an extraction of 95 per cent of gold is made. Up to 1913 a total of about $3,250,000 in gold has been recovered from Nickel Plate ores mined.

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## ANNOTATED GUIDE.

Miles and Kilometres.

124 m. 200 km. **Bromley**—For four miles (6·4 km.) beyond Hedley the rocks along the railway

133 m. 214 km. **Allison**— are Palæozoic slates, limestones, and schists, good exposures of which can be seen in the bluffs which face the river at several points. Shortly after crossing Sterling creek, the railway enters a batholithic body of

Miles and Kilometres.

granodiorite, which extends up the valley for about 10 miles (16 km.) to Five Mile creek. In the granodiorite the valley is narrower and more steep-sided, and the solid rocks are exposed in many of the cliffs. After passing Five Mile creek the granodiorite is again replaced by Palæozoic slates and limestones, the contact zone of which is marked by a number of reddish dykes of granite porphyry cutting the sedimentary rocks. From this point onward to Princeton the hills bordering the valley become lower and more open, and soon after passing Allison the railway crosses the Similkameen river and enters the town of Princeton.

136 m. 219 km. **Princeton**—Altitude 2,120 ft. (646·15 m.).

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## GEOLOGY OF THE REGION AROUND PRINCETON.

### GENERAL DESCRIPTION.

Princeton is situated at the junction of the Similkameen and Tulameen rivers, in a shallow depression in the Interior Plateau region, which was formerly an Oligocene lake basin. The region is characterized by comparatively moderate relief, gently rounded hills and broad, open valleys. It is sparsely forested, and in portions quite open and grassy, so that it affords good grazing for horses and cattle.

The principal rocks of the region are flat lying sediments of Oligocene age, resting on a basement of tilted Palæozoic rocks. They include sandstones, clays, shales, conglomerate, and coal seams, and contain a variety of fossil plants, insects, and fish remains. These rocks are overlaid by volcanic flows of andesite, basalt and fragmental materials.

The Palæozoic rocks, to the south of the town of Princeton, at Copper Mountain, contain low grade copper deposits of considerable magnitude, which are now being vigorously prospected. They carry chalcopyrite as the principal copper mineral, and are either in the form of contact metamorphic deposits situated in altered sedimentary rocks at the contact of irruptive igneous bodies, or

are in fissures in both the igneous and sedimentary rocks.

The Oligocene rocks cover an area of about 40 square miles (103 sq. km.) and contain a number of seams of coal, ranging in thickness from a few feet up to 60 feet (18·29 m.). Some of the seams are being mined. The Oligocene also includes important beds of clay which are utilized in the manufacture of cement.

## PARTICULAR DESCRIPTION.

The chief features of geological interest to be seen in the vicinity of Princeton are the rocks of the Tertiary lake basin, with the coal seams which are associated with them.

In a low cliff within a few yards of the railway station a good exposure of Oligocene sandstone is seen, The sandstone is a light coloured, coarse grained, feldspathic rock dipping at a low angle towards the southwest. It shows false bedding, and has been eroded by wind or water action to form deep caves, the roof of the caves being a hard compact bed of sandstone.

On the east side of Similkameen river, at the end of the traffic bridge, the outcrop of a coal seam is seen. The total thickness of the seam is 25 feet (7·6 m.), but it contains several small bands of clay. The associated rocks are shale and sandstone. The coal dips S. 30° W. at an angle of 12 degrees and is traversed by a few normal faults which strike S. 45° W. The throw is usually only a few feet, the downthrow being on the northwest side. The mineable parts of the seam are a bench 7 feet (2·13m.) to 10 feet. (3·04 m.) thick in the upper half, and another bench 7 feet (2·13 m.) thick in the lower half. Only the upper bench is at present being worked.

The coal is sub-bituminous, excellent for domestic use and for the manufacture of gas. A sample of the seam being mined gives the following proximate analysis:—

| | | |
|---|---|---|
| Moisture | 16·17 | per cent. |
| Volatile combustible matter | 37·58 | " |
| Ash | 4·58 | " |
| Fixed carbon | 41·67 | " |
| | 100·00 | |

## Industrial Notes.

Coal mining is the principal industry carried on in the neighbourhood of Princeton. The coal-bearing rocks cover an area of about 40 square miles (103 sq. km.) and virtually the whole of this area is taken up in coal claims. Prospecting and development work are being carried on at a number of points in the basin, but shipment of coal is being made only from the collieries of the Princeton Coal and Land Company, situated on the east side of Similkameen river, near Princeton. The coal is mined by an entry driven on the dip of the seam. The method employed is pillar and room, with the use of coal cutting machines.

Two and a half miles (4·02 km.) southeast of Princeton, cement works have been erected, which are capable of manufacturing 2,000 barrels of cement daily. The raw materials for the cement are all obtained from a thick bed of Oligocene age, and the lime from a bed of pure crystalline limestone in the Palæozoic rocks underlying the Oligocene.

On Copper Mountain, 12 miles (19·3 km.) south of Princeton large bodies of low grade copper-gold ore are being actively prospected by the British Columbia Copper Company, and it is expected that actual mining will soon be under way.

## References.

**1.** Camsell, Charles.....Preliminary Report on Part of the Similkameen District, G.S.C., No. 986, 1906.

## ANNOTATED GUIDE (Continued).

Miles and Kilometres.

136 m.
219 km.

**Princeton**—Alt. 2,120 (646·15 m.). On leaving Princeton the railway follows the valley of the Similkameen river for a short distance, and then enters a tunnel which cuts through a narrow neck separating the Similkameen from Tulameen valley. From this point westward to Tulameen the line lies in Tulameen valley passing from one side of the river to the other as is found necessary.

Miles and Kilometres.

The famous Vermilion cliffs are situated on the north bank of Tulameen river about 2 miles (3·2 km.) beyond Princeton. The colour of the cliffs is due to the combustion of a coal seam, ignited, probably, by the lava which overlies it immediately to the west. The river takes its name from the cliffs, "Tulameen" being a local Indian name meaning red earth. The rocks of Vermilion cliffs contain many fossil plants.

The sedimentary Oligocene rocks are overlaid a short distance west of Vermilion cliffs by volcanic flows, and for the next three miles (4·8 km.), exposures of the two formations can be seen in the cliffs bordering the river and in the railway cuttings. Turning a sharp bend in the valley, the Tertiary rocks are replaced by Triassic rocks, consisting largely of volcanic materials with only a few sedimentary beds, and these persist almost all the way to Tulameen. These rocks are unfossiliferous, but from lithological characteristics are correlated with Dawson's Nicola series.

Placer mining for gold and platinum was at one time carried on in Tulameen valley from Princeton up to Champion creek, a distance of 28 miles (45 km.). Some of the placers were worked as early as 1860, but it was not until the discovery of coarse gold in Granite creek in 1885 that much interest was taken in them. Granite creek, which enters Tulameen river one mile below Coalmont, was the most productive stream, and the whole district at one time was the biggest producer of platinum on the continent. Some payable ground still remains on the main river and on a few of its southern tributaries, but the more easily worked deposits have long been exhausted.

148 m. 238 km. **Coalmont**—Alt. 2,450 ft. (746·7 m.). Coalmont is a new town that has sprung up within the last two years as the result of the development of a coal basin on the southern side of the river at that point. The basin is of Oligocene age covering about 5 square miles, and contains a considerable quantity of coal much of

Miles and Kilometres.

which is bituminous in character. The outcrop of the coal seams lies at an elevation of about 1,300 feet (396·2 m.) above Tulameen river. The coal-bearing rocks dip into the mountain side and rest on a floor of tilted Triassic rocks. They are unconformably covered in part by a flow of olivine basalt. A tunnel has been driven 1,800 feet (548·6 m.) through Triassic rocks, and cuts the coal-bearing rocks at a depth of 700 feet (213·3 m.) below the outcrop.

152 m. 244·6 km. **Tulameen**—Alt. 2,550 ft. (777·2 m.). Four and a half miles (7·24 km.) west of Coalmont is the town of Tulameen situated at the junction of Otter and Tulameen valleys. From this point a subordinate excursion is made up Tulameen valley for the purpose of seeing some of the platinum-bearing placers, and the original locality from which diamonds were first found in place in Canada.

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## GEOLOGY OF THE REGION AROUND TULAMEEN.

### GENERAL DESCRIPTION.

The Tulameen district is situated on the western border of the Interior Plateau of British Columbia, and a few miles east of the Hope Mountain range, which is a part of the Cascade system. The district has, in the main, the general characteristics of plateau topography with a slightly greater elevation and vertical relief owing to its proximity to the Cascade mountains.

The oldest rocks of the district consist of highly inclined green schists, andesites, limestones and argillites. These rocks are called the Tulameen series and are correlated with Dawson's Nicola series which is Triassic in age. The Tulameen series is intruded by batholithic bodies of granite and granodiorite, as well as by a stock-like mass made up of peridotite, pyroxenite, and gabbro, which are transitional into each other. These rocks are all of Jurassic age. Overlying them unconformably are slightly inclined Oligocene volcanic and sedimentary rocks,

General view of Interior Plateau region at Tulameen.

which are themselves intruded by a body of Tertiary granite. The youngest rock in the district is a flat-lying flow of olivine basalt, covering a limited area to the south east of Tulameen.

The history of the region as recorded in the rocks may be broadly summarized as follows:

(1) Deposition of Triassic sediments and volcanics.

(2) Mountain building and folding of the Triassic rocks.

(3) Batholithic intrusion of granite, peridotite and pyroxenite, and granodiorite in Jurassic period.

(4) Laramide revolution.

(5) Eocene erosion period.

(6) Extrusion of lavas, followed by deposition of coal-bearing sediments in the Oligocene period.

(7 Batholithic intrusion of granite in Miocene period.

(8) Erosion period.

(9) Extrusion of olivine basalt.

(10) Uplift of Cascade mountains and Interior Plateau in Pliocene times, followed by deepening of valleys.

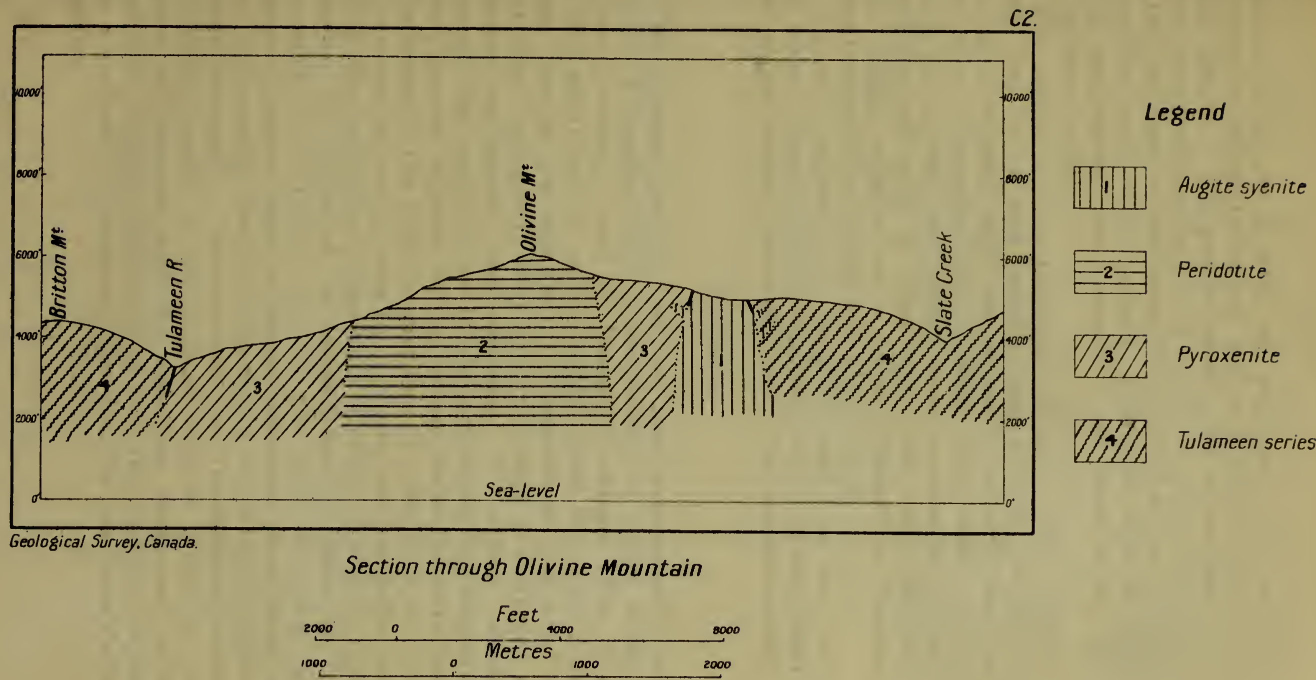
(11 Glacial period.

(12) Post-Glacial uplift, and deepening of upper portion of Tulameen valley.

A variety of mineral deposits are found in the rocks of the district. The Triassic rocks contain veins and replacement deposits of gold and copper. Segregations of magnetite and chromite occur in pyroxenite and peridotite. The peridotite also contains both platinum and diamonds, usually associated with the chromite segregations. Coals are found in the sedimentary rocks of Oligocene age, and the placers of the district have yielded gold and platinum in considerable amount.

## PLATINUM PLACERS.

The principal streams in the district on which platinum bearing gravels have been found are: Tulameen river below Champion creek; Slate creek; Granite creek; Newton creek. The gravels are post-glacial in origin, and are found in the stream beds and on the sides of the valleys at elevations not greater than 250 feet (76·2 m.) above the streams. Except in Tulameen river below Slate creek they are not of very great extent. All the payable




Section through Olivine Mountain

gravels contain both gold and platinum, the proportion varying in different streams and in different parts of the same stream. This proportion of gold to platinum varies in the streams mentioned from 4 to 1 to 1 to 1. The source of the platinum has definitely been traced to the elongated peridotite stock which crosses Tulameen river at Eagle creek and extends south-easterly from there to the head of Newton creek.

The mining of the platinum placers, which began in 1885, has up to now usually been carried on only by individual miners with the ordinary methods that such men use. Attempts have, however, been made at Eagle creek, Slate creek, and Granite creek to mine by hydraulic methods, but none of these have been very successful. Old working may be seen at several points on Tulameen river between Slate creek and Eagle creek.

The total amount of platinum obtained from the gravels has been variously estimated at 12,000 to 20,000 ounces. The present output, however, is only a few ounces annually.

## DIAMONDS.

The diamond bearing rocks are most conveniently seen on the Tulameen river at the mouth of Eagle creek, 8 miles (12·8 km.) west of Tulameen village. The river at this point cuts a valley nearly 3,000 feet (914·4 m.) deep, through the middle of a large stock composed of peridotite, pyroxenite and gabbro, which is intrusive in Triassic sediments and volcanics. A vertical section through the stock, given in the accompanying diagram, illustrates the relations of the various rocks to each other. The centre of the stock is composed of peridotite, and this is surrounded on all sides by a border of pyroxenite into which the peridotite passes by a gradual change in composition, the olivine of the one rock being replaced by the pyroxene of the other. Outside the pyroxenite is a thin border of gabbro, which in places passes into an augite syenite. The syenite however also occurs in intrusive relation to the pyroxenite. It seems clear that the three rocks were originally present in one common magma, which, in the course of injection into the overlying rocks and while gradually cooling, differentiated into three distinct types, the most basic in the central part and the most acid on the outside.

Chromite occurs in the peridotite in short irregular veins and in bunches, which are clearly segregations developed in the magma during cooling. Analyses made by Mr. R. A. A. Johnston of the Geological Survey of some of these chromite segregations, taken from the north slope of Olivine mountain, yielded both platinum and diamonds in variable amount. In making the original analysis the chromite was separated into two parts, a magnetic and a non-magnetic part. The non-magnetic part yielded three per cent of diamond, and the magnetic part six per cent.

The diamond product obtained disintegrated to a powder shortly after being released from the rock, and the disintegrated particles were found on examination under the microscope to be individual crystals. Studied in thin sections, the diamonds were found to occupy small veinlets traversing the chromite.

Since the discovery of diamonds in the solid rocks the gravels of Tulameen river have been carefully examined. Gravel taken from the river in the neighbourhood of Eagle creek was panned, and a large number of small diamonds obtained along with the black sand. Small rubies were also found to be present.

Some prospecting for diamonds of commercial size is being carried on in the valley of Tulameen river, but up to the present the results have not been satisfactory. Some diamonds have been obtained, but the largest is not bigger than a pin's head.

## References.

**1.** Kemp, J. F.......... U.S.G.S. Bulletin No. 193, 1902.
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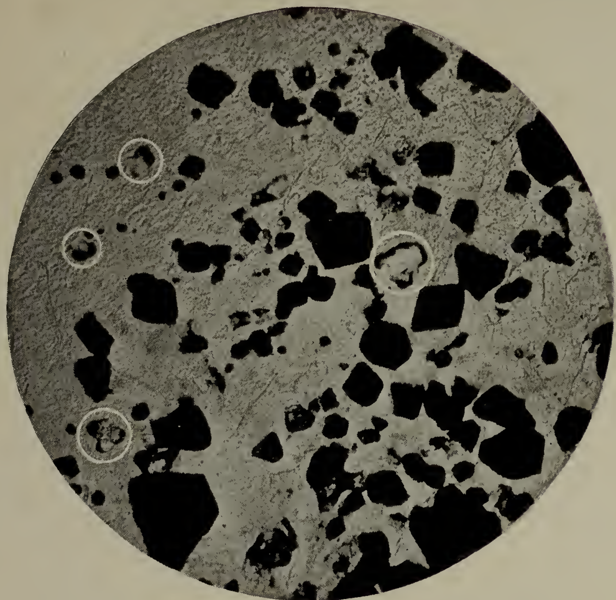
**3.** ...................... Platinum Mining in the Tulameen District, Can. Min. Inst. Vol. 13, 1910.
**4.** ...................... A new Diamond locality in the Tulameen District. Econ. Geol. Vol. 6, No. 6, 1911.



Thin section of peridotite, showing the occurrence of diamonds (within white circles) associated with chromite.

Thin section of chromite segregation in peridotite, showing the occurrence of diamonds in veinlets.

Miles and
Kilometres.

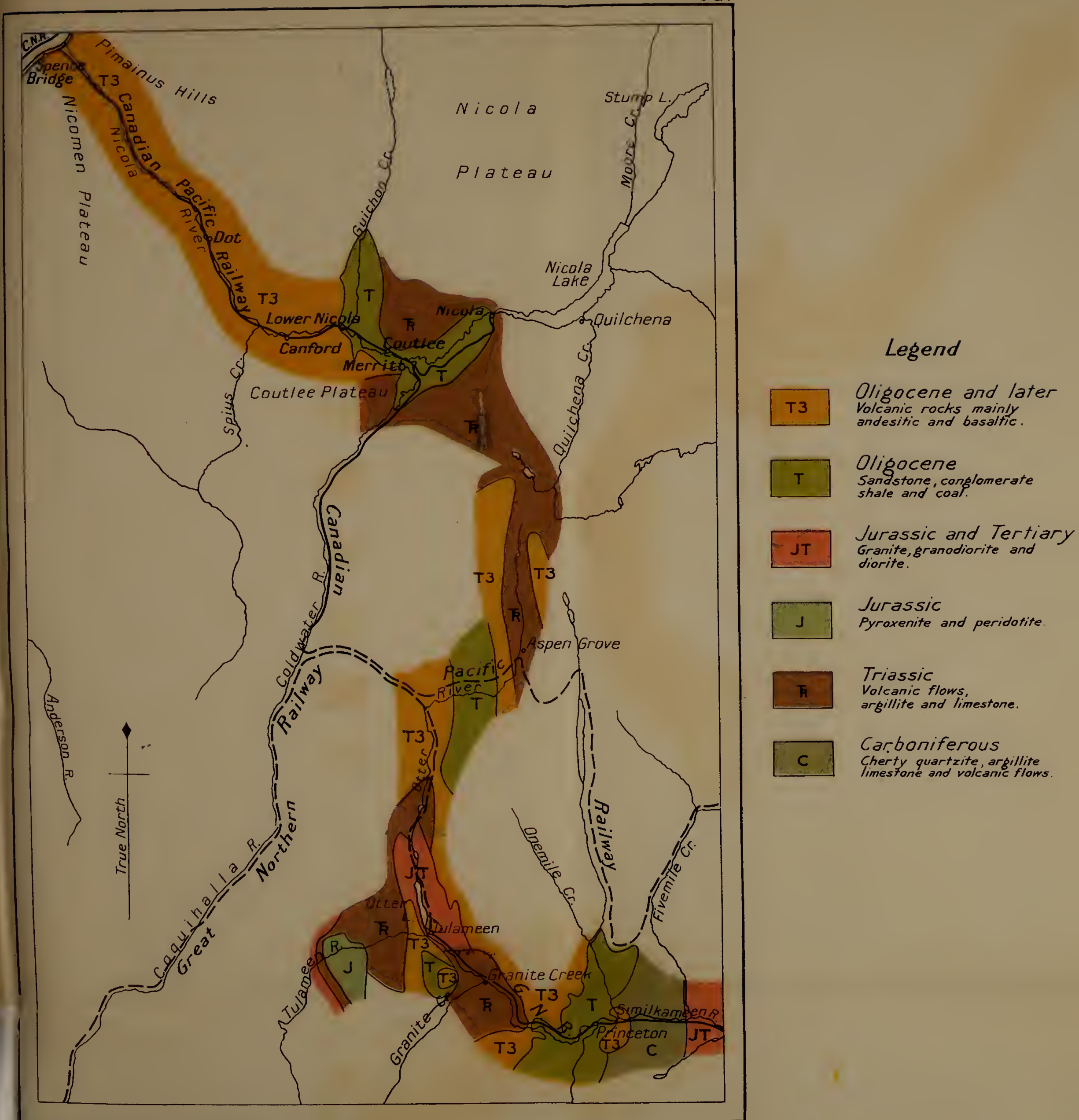
0. m. **Tulameen.**—Alt. 2,550 ft. (777·2 m.).

0. km. **Otter Valley**—Between Tulameen on the Great Northern railway and Merritt on the Canadian Pacific, a distance of 53 miles (85·3 km.), there is at present no railway connection and this portion of the route has to be made by carriage.

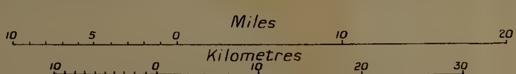
On leaving Tulameen the road runs northward up Otter valley, skirting the western shore of Otter lake for a distance of three miles (4·8 km.) in the course of which numerous exposures of a Tertiary granite are seen. Otter valley for 18 miles (28·9 km.) or as far as the forks, is a fairly broad, flat-bottomed valley, showing evidence in its shape of having been occupied by a valley glacier moving southward. It is typical of a number of deep trench-like valleys that have been developed in the Interior Plateau region. The rocks, besides the granite already mentioned, consist of Triassic schists, greenstones, and limestones extending as far as Thynne creek, beyond which younger Tertiary lava flows overlie them.

18 m. **Canyon House**—At the forks of the valley,
28·9 km. where the Canyon House is situated the valley appears to end abruptly, but the road turns sharply to the east following a narrow gorge for a few miles. In this gorge narrow beds of Tertiary sediments, which may be correlated with Dawson's Tranquille beds, rest on top of lavas and tuffs, and are covered conformably by a thick flow of columnar basalt.

Leaving Otter creek the road mounts the western slope of the valley to an elevation of 3,400 feet (1,036·3 m.) where it is virtually at the general level of the Interior Plateau. The main characteristics of the plateau are here well seen, and for the next 25 miles (40·2 km.) the road continues across the upper levels of the plateau running through an open, rolling, park-like country, which in springtime is one of the




Geological Survey, Canada.
Route map between **Princeton** and **Spence Bridge**



Miles and Kilometres.

most beautiful parts of British Columbia. The country is open and grassy, or sparsely forested with large pines and dotted here and there with lakes and ponds: it is one of the best cattle raising districts in the Province.

27 m.
43·4 km.

**Aspen Grove**—Alt. 3,200 ft. (975·3 m.). Near Aspen Grove, a ranch and post office, 25 miles (40·2 km.) from Merritt, the road again descends to Otter creek, which now occupies a broad, shallow trough, incised through Tertiary lavas into Triassic rocks which underlie them. On the east side of the valley are some native copper deposits, which occur as narrow fissure fillings in the Tertiary lavas. Some mining has been done on these deposits, and a slab of native copper weighing 600 pounds is stated to have been obtained from one of the mineral claims.

**Nicola Valley**—The highest point of the road, 3,500 feet (1,066·8 m.), above sea level is reached at an old lime kiln about nine miles (14·5 km.) from Merritt, three miles (4·8 km.) beyond which the road suddenly emerges from the forested country on to the open slope of Nicola valley. Here a most delightful view is obtained, and one is well rewarded by a stop of a few minutes to enjoy it. The bottom of the valley lies 1,500 feet (457·2 m.) below and several miles of its length can be seen from this point. Around and behind the shoulder of the hill to the north-east lies the town of Nicola, situated at the west end of Nicola lake, and directly west where the valley of Coldwater river joins that of Nicola river, can be seen the coal mines of Middlesboro and the town of Merritt, distant seven miles (11·2 km.).

52 m.
83·7 km.

**Merritt**—Alt. 1,900 feet. (579·1 m.).

# GEOLOGY OF THE REGION ABOUT MERRITT.

## GENERAL DESCRIPTION.

The town of Merritt is situated in Nicola valley at the junction of Coldwater river with the Nicola. The district lies in the Interior Plateau region into which Nicola river has cut one of those deep, wide valleys, characteristic of the region. The bottom of the valley is about 1,900 feet (579 m.) above sea level, while the surrounding country stands 1,500 feet (457 m.) higher. The country is open or only sparsely timbered, and the slopes, though often steep, are generally covered by a thick mantle of drift.

The oldest rocks of the district are of Triassic age, and belong to the Nicola series. They consist of folded and metamorphosed volcanic flows, and some limestone and argillite. Unconformably above them are the coal-bearing Oligocene rocks which consist of sandstone, conglomerate, shale, and coal. These again are overlaid in places by more recent basaltic flows.

## PARTICULAR DESCRIPTION.

The importance of the district about Merritt depends primarily on the presence of Oligocene rocks containing bituminous coals.

Like other Oligocene areas in British Columbia the rocks about Merritt are believed to have been deposited in a lake basin and since elevated to their present position. The basin covers a superficial area of about 40 square miles (103 sq. km.) all of which, however, does not appear to be underlaid by coal. The rocks consist of sandstones, shales, and conglomerates, which dip at angles varying from 10 to 40 degrees. In places the strata have been folded into anticlines, and in others faulted and considerably displaced. They contain a variety of fossil plants from which their age has been determined.

The best natural section of these rocks is that exposed in Coal gully west of the town of Middlesboro. This was measured by G. M. Dawson of the Geological Survey of Canada, and in his report of 1877-78 [**1**] he gives the following section in descending order:—

| | Ft. | in. | |
|---|---|---|---|
| Soft yellowish sandstone in thin beds.......... | 32 | 0 | ( 9·7 m.). |
| Coal, laminated, rather soft,.................. | 15 | 4 | ( 4·6 m.). |
| Sandstone, rather soft, with some shale........ | 89 | 0 | (27·1 m.). |
| Coal.................................... | 5 | 4 | ( 1·6 m.). |
| Sandstone, with shale at the base............. | 141 | 0 | (32 m.). |
| Coal, about............................... | 3 | 0 | ( ·9 m.). |
| Sandstone, in thin beds...................... | 136 | 0 | (33·2 m.). |
| Coal, about............................... | 2 | 5 | ( ·76 m.). |

It is not definitely known how many workable seams of coal are contained within this basin, but there are four outcropping and being worked in the neighbourhood of Coal gully, and two or three others in adjacent ground to the east, each of which however may be correlated with one or another of the four known seams. In the mines of the Nicola Valley Coal & Coke Company these four seams have thicknesses of 6, (1·8 m.), 10 (3·04 m.), 5 (1·5 m.) and 12 feet (3·6 m.) respectively.

An analysis of a sample of coal taken by R. W Ells [2] of the Geological Survey and analysed in the laboratory of the Survey is given below, and probably represents the general character of the coals of this field:

| | | |
|---|---|---|
| Water........................... | 3·04 | per cent. |
| Volatile combustible matter...... | 37·18 | " |
| Fixed carbon.................... | 52·05 | " |
| Ash (reddish white)............. | 7·73 | " |
| | 100·00 | " |

Coke, per cent, 59·78. Firm, compact and coherent.

An estimate made by D. B. Dowling of the Geological Survey placed the total quantity of coal in this field at about 200 million tons.

## INDUSTRIAL NOTES.

Four companies are actively engaged in mining operations in this field, namely, the Nicola Coal & Coke Company, the Inland Coal & Coke Company, the Diamond Vale Coal & Iron Mines, and the Pacific Coast Collieries. The Inland Coal & Coke Company is producing about 100 tons of coal per day, while the Nicola Valley Coal & Coke Company produces annually about 200,000 tons. Room and pillar is the method of mining employed, and no coal cutting machines are used. The mines give employment to about 400 men.

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**1.** Dawson, G. M. Geol. Surv. of Canada, 1877-78.
..................Geol. Surv. of Canada. Vol. 7, part B. 1894.
**2.** Ells, R.W. Geol. Surv of Canada, Vol. 16. p. 42-A. 1904.
**3.** Porter and Durley, Coals of Canada, Dept of Mines, 1912.

ANNOTATED GUIDE—(Continued).

| Miles and Kilometres. | |
|---|---|
| 0 m.<br>0 km. | **Merritt**—Alt. 1,900 ft. (579·1 m.). Leaving Merritt on a branch of the Canadian Pacific railway which connects with the main line at Spence's Bridge, the course followed is westward down he broad, flat-bottomed valley of Nicola river. |
| 2 m.<br>3·2 km. | **Coutlee**—The railway crosses Nicola river about a mile beyond Merritt and **Coyle**— passes through the small villages of Coutlee and Coyle, both of which are situated on the Oligocene coal-bearing rocks of the Coldwater series. Coyle is situated at the mouth of Guichon creek, up whose valley to the northward the same rocks extend for several miles. |
| 12 m.<br>19·3 km. | **Canford**—From this point downward to the Thompson river the prevailing rocks are lava flows of Tertiary age, with which, however, are associated narrow beds of coarse conglomerate and sandstone belonging to Dawson's Tranquille beds. |
| 20 m.<br>32·2 km. | **Dot**— Below Dot the valley narrows and **Clapperton**— its grade steepens. Cliffs of white glacial silt and gravel, weathering into fantastic shapes, are frequently seen down as far as Spence's Bridge, where the Nicola river joins the Thompson. |
| 41 m.<br>66 km. | **Spence's Bridge**—Alt. 760 ft. (231·6 m.). From Spence's Bridge to Victoria Excursion C 2, follows the route of C 1. (See Part II., Guide Book No. 8.) |

## REVELSTOKE TO VICTORIA.

From Revelstoke to Vancouver the route coincides with that of Excursion C1 and a description of this section is given in Guide book No. 8, Part II. The subordinate excursion to the Nanaimo coal field, which diverges at Vancouver and rejoins the main excursion at Victoria is also described in Guide book No. 8, Part III.

## VICTORIA, BRITISH COLUMBIA TO CALGARY, ALBERTA.

The east bound portion of C2 Excursion follows as far as Calgary the same route as that taken in the westward journey of C 1 the guide to which is given in Part II of Guide Book No. 8.

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## CALGARY, ALBERTA, TO WINNIPEG, MANITOBA VIA GRAND TRUNK PACIFIC RAILWAY.

BY

D. B. Dowling.

### CALGARY TO TOFIELD.

ANNOTATED GUIDE.

Miles and Kilometres.

**Calgary**—Altitude 3,425 ft. (1,044m). From Calgary to the crossing of Red Deer river, the country is underlain by sandstones of the Paskapoo series of early Tertiary age. At the crossing of the Red Deer, the outcrops show the basal beds of the Paskapoo and the coal seams (measures) that mark the top of the Edmonton (Cretaceous). This horizon is marked by a very persistent coal seam which is mined at intervals east of the railway along the Rosebud, Kneehill, Threehill and Ghostpine creeks. From Red Deer river nearly to Battle river,

Miles and Kilometres.

the same horizon is followed but the area is drift covered and outcıops are rare.

The valley of Battle river is eroded in the shales and sandstones of the Edmonton series. As Camrose is approached coal seams are again in evidence, several of which underlie the town.

The country between Camrose and Tofield is rolling and partly wooded. The coal seams in this area are being mined in a small way, where the overburden of drift is thin.

**Tofield.**—Altitude 2289 ft. (697m).

## TOFIELD, ALBERTA, TO TETE JAUNE, BRITISH COLUMBIA.

### ANNOTATED GUIDE.

Miles and Kilometres from Winnipeg.

The area traversed by the railway between Tofield and Parkgate is underlain by the rocks of the Edmonton formation, with possibly a band of overlying Paskapoo which extends northwards and may cross the railway between Junkins and Leaman. Westwards, between Hinton and Parkgate, Cretaceous rocks lower than the Edmonton may be found to outcrop. Throughout this whole belt the strata in the eastern half are but slightly inclined to the west, while in the western half they are practically horizontal.

The Edmonton formation consists of a series of shales and sandstones, often merely clays and sands, deposited during the period of brackish water which succeeded the marine invasion of the central part of the continent during early and mid-Cretaceous times. The formation is very rich in coal seams denoting periods of abundant vegetation. The coal-bearing beds of the Edmonton formation are exposed over an area of 30,000 square miles.

752 m. **Tofield**—Altitude 2,289 ft. (697m). To the
1,310 km. east and south of the junction of the Calgary

Miles and Kilometres.

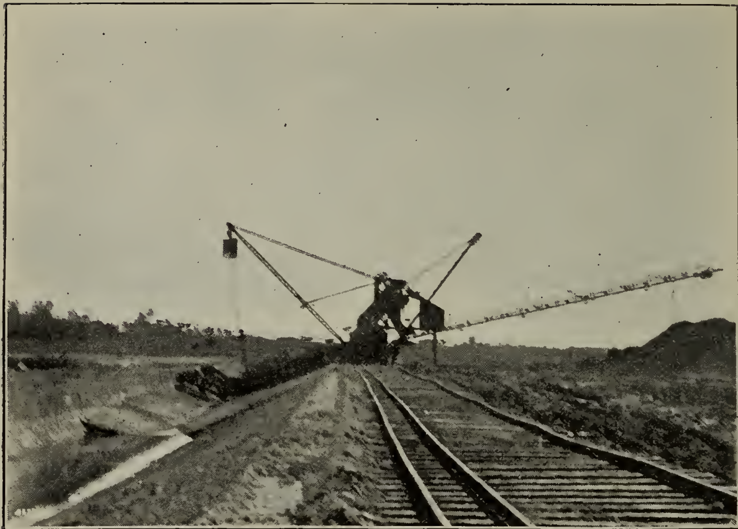
branch with the main line, the low plateau facing north is underlain by a coal seam with an average thickness of nine feet (2·7m) overlain by a slight thickness of sandy shales, clay and boulder clay, or by the latter alone. On the property of the Tofield Coal Company the overburden is mainly shales and sandstones and the mantle of drift is quite thin, but on the Dobel property to the east the original cover is thinner but there is a greater thickness of boulder clay which includes detached and turned up rock masses of the original cover. The portions of the seam, where stripped by the glacial advance and re-covered with boulder clay, are much more weathered. Steam shovels and Lubecker excavators are used in removing the over-burden, and the coal is mined in open quarries.

At the town of Tofield, where this seam is entirely eroded away, a boring was made down to the top of the Belly River formation. The following is a generalized summary of the section:—

| | | Feet. | Metres. |
|---|---|---|---|
| Edmonton | Shales and sandstones | 200·0 | 60·90 |
| | Coal | 2·0 | 0·60 |
| | Parting | 1·5 | 0·33 |
| | Coal | 5·8 | 1·76 |
| Pierre | Shale | 740·6 | 225·10 |
| Belly River | Coal | 1·0 | 0·30 |
| | Shales and sands | 100·0 | 30·48 |
| | Coal | 4·0 | 1·21 |

Just below the horizon of the lowest coal seam, gas and water were found. Further drilling operations are under way to thoroughly test the importance of the gas-bearing horizon.

793 m. **Edmonton**—Altitude 2,179 ft. (664 m.).
1,276 km. Edmonton is situated on the Saskatchewan river 793 miles (1,276 km.) west of Winnipeg. The stream has cut a valley over 165 feet (50·4 m.) deep, the sides of which afford sections, at frequent intervals, of the Edmonton rocks. Workable coal seams outcrop at Clover Bar, 5 miles (8 km.) east of the city, and these con-



Lubecker excavator, Tofield Coal Co.


Steam Shovel, Dobel Coal Co.
Stripping coal at Tofield, Alta.

Miles and Kilometres.

tinue with slight westerly dip to the city itself. The seam has an average thickness of a little over 5 feet (1·5 m.). Between 15 and 20 feet (4·5 to 6 m.) below this seam there are evidences of another seam from 4 to 7 feet (1·2 to 2·1 m.) thick which may be distinct from that at Clover Bar. The coal is sub-bituminous, and is suitable for domestic and power purposes but requires care in shipment and storage.

Alluvial gold has for many years been washed from the bars in the Saskatchewan, both above and below Edmonton. Gravel dredged from the bed of the river is used extensively in road making. In the washing and crushing operations a small amount of gold is recovered daily.

837 m. **Wabamun**—Altitude 2,380 ft. (725 m.).
1,347 km. Westward to Wabamun the surface is gently rolling with an absence of outcrops of the underlying rocks. Between Wabamun and Fallis, on the north shore of Wabamun lake, the upper part of the Edmonton formation is exposed, the outcropping shale including a seam of sub-bituminous coal being reported to be from 18 to 22 feet (5·4 to 6·6 m.) thick with a small parting in the centre of the seam.

851 m. **Gainford**—Altitude 2,435 ft. (742 m.). The
1,369 km. coal seam outcropping on Wabamun lake dips to the west and is mined at Gainford at a depth of 138 feet (42 m) at which point it was found to have a thickness of 10 feet (3·04 m.).

859 m. **Entwistle**—Altitude 2,566 ft. (782 m.). The
1,382 km. valley of Pembina river, which is crossed at this point, is about 100 feet (30 m.) deep. A 10 foot (3 m.) seam of coal outcrops near the bottom of the valley, while upstream from Entwistle several other exposures show much thicker seams, one of which is stated to be 26 feet (7·8 m.) thick. These seams belong to the upper horizon of the Edmonton, in which coal is found in almost continuous beds from this point to Crowfoot, on the main line of the Canadian Pacific railway, a distance of 245 miles (390 km.).

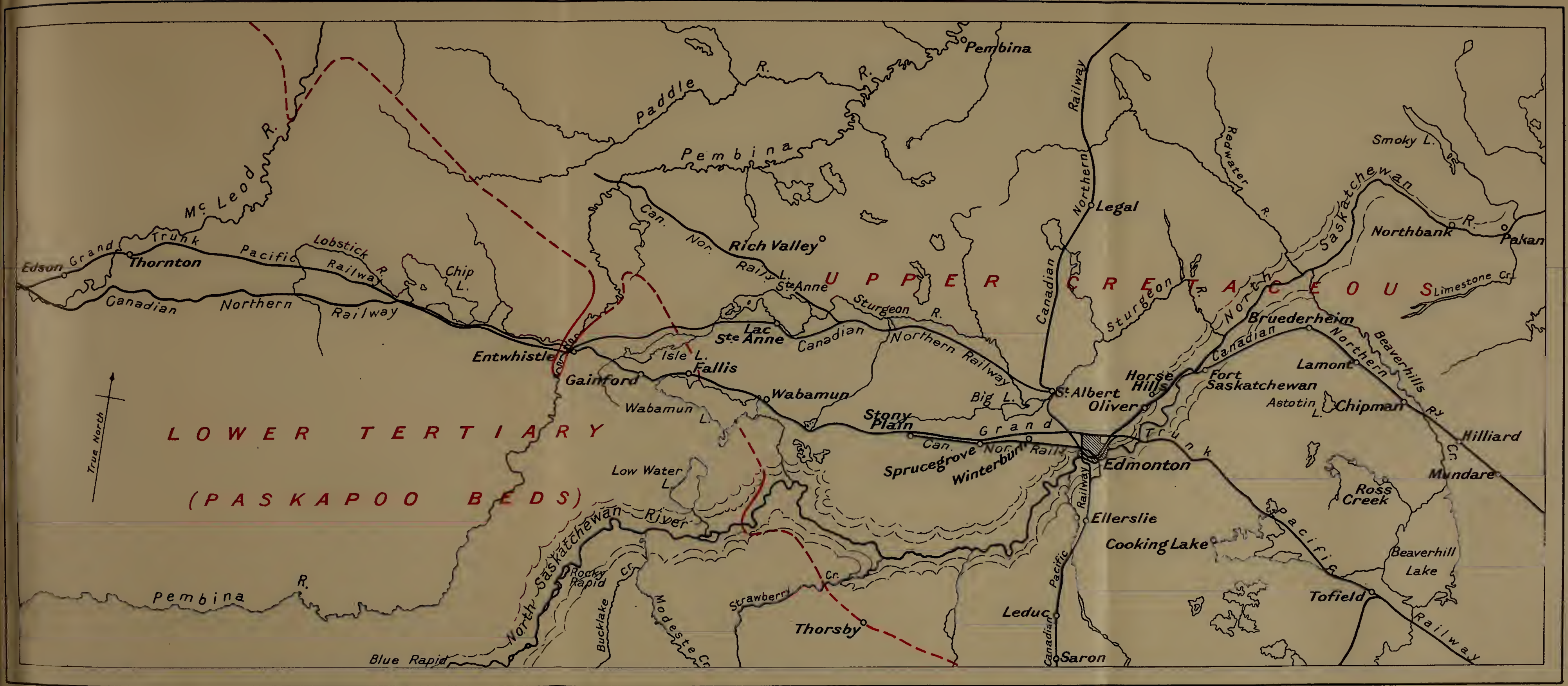
Miles and Kilometres.

932 m. 1,600 km. **Bickerdike**—Altitude 3,110 ft. (948 m.). A branch railway from this point runs south to the headwaters of Embarras and Little Pembina rivers, where the coal seams of the Edmomton formation are brought to the surface in the outer foothills. Mines are there in operation and are the forerunners of others to be opened later on the very rich measures of the Brazeau, which occur nearer the mountains. This field and its extension northward contains a very large reserve of both coking and steam coal. Other industries dependent on the transportation facilities afforded by the railway include a cement factory, situated at Marlborough, 8 miles (12·8 km.) west of Bickerdike. The materials used are marl from a lake basin and clay from a nearby sedimentary deposit.

958 m. 1,542 km. **Obed**—Altitude 3,560 ft. (1,085 m.). Surface deposits of this vicinity show erratics derived from the mountains to the west and possibly also from an eastern source, the latter, perhaps, having been transported westward by the Keewatin glacier. The elevation of the railway at this point is only 200 feet (61 m.) below that of the divide in the pass across the mountains.

978 m. 1,574 km. **Hinton**—Altitude 3,325 ft. (1,013 m.). To the north can be seen the valley of Athabaska river flanked by terraces, on one of which the railway has been built. The rocks of the Edmonton series, which to the east of this point dip at low angles, or lie nearly flat, here have an easterly dip. Westward this dip increases and the strata become folded and faulted to such an extent that the region has been termed the "disturbed belt" of the foothills.

**Brulé lake**—For about six miles (9·6 km.) the railway follows the eastern shore of Brulé lake, which is a shallow basin gradually being silted up by the detritus carried down from the mountains by the Athabaska river. Inside the mountains other portions of the valley show the completion of this process of silting up and the incision of a channel across the basins.




Geological Survey, Canada.

Route map between **Edmonton** and **Edson**

Miles
5 0 10 20 30 40

Kilometres
5 0 10 20 30 40 50 60

Miles and Kilometres.

The first or outer range of the Rocky mountains stands out prominently on the western side of Brulé lake, and the structure there displayed is that of an overthrust block of Devonian limestone superposed on Lower Cretaceous.

## ROCKY MOUNTAINS.

The fault block system of mountain building observed in the southern sections of the Rocky mountains is modified in this section by the substitution of sharp folding for minor faulting, and the blocks between the major faults show complex folds in the beds and are much wider. Two large blocks, whose elevated eastern edges form Roche Miette and Bulrush mountain, exhibit this folding, while the valley depression between the two is underlain by Lower Cretaceous rocks containing coal. Mines are being established on both sides of the valley. The lowest rocks outcropping here are of Cambrian age and underlie a series of sediments capped by fossiliferous Devonian limestone, which is exposed in the cliff of Roche Miette. The Cambrian rocks are disposed in a yellow band near the fault line which separates the lower rocks from the Cretaceous. The succeeding fault blocks are tilted, but not folded, and in that respect resemble the mountains to the south.

The structural section of the mountains on the Athabaska shows a modification in the outer ranges of the fault block system exhibited on the southern passes. The outer blocks have been deformed by sharp folds, which when traced southward develop into faults, and separate the block into several smaller blocks. Two of the blocks showing this contortion are seen from Pocahontas station. The eastern one of these has its uplifted edge fronting to the east on Brulé lake: the second forms Roche Miette, the depressed edge being beneath the valley of Rocky and Stony rivers. Cretaceous beds are found at the back of the first block; some of these beds may also remain on the second, but they are masked by the great deposit of detrital matter in the two valleys mentioned.

The rocks forming these blocks include a series of sediments ranging in age from Lower Cretaceous downward to Upper Cambrian, all in apparent conformity. The lowest sediments are at the base of the second block. The character of these beds is outlined below:—

Folds in Outer range south of Athabaska river.

**Cretaceous.**—Rocks of this age include sandstones and shales of about the horizon of the Kootenay formation, and contain plant remains and coal seams. Fresh water conditions are indicated, although in the lower part, salt water deposits are not wanting. Of the plant remains the following have been collected in this locality:—

*Podozamites lanciolatus, Sequoia richenbachii, S. smittiana, Oleandra gramniaefolia* and *Zamites acutipennis.*

**Jurassic.**—This formation is made up mostly of black shales holding *Belemnites*. Included in it are two sandstone ribs, the upper with *Arctica occidentalis* and *Nemodon sulcatinus*, and the lower, lying practically at the base of the formation, shows remains of *Gryphaea planoconvexa, Ostrea strigicula* and a species of *Terebratulina.*

**Triassic and Permian.**—Some reddish shales and dolomites resting on yellow to brown shales and quartzites have been referred to these periods, but have not been examined in detail.

**Carboniferous.**—In the Banff section the Carboniferous limestone forms a prominent heavy bed. Northward this formation thins considerably, and is here represented by thin bedded limestones, and possibly by some of the quartzitic layers mentioned above.

**Devonian.**—The heavy limestone beds, which form the outer mountains, appear to be mostly of this age. Two limestone beds appear, in the upper of which both Devonian and lower Carboniferous fossils occur, but the line of demarcation between these two periods has not been determined. Typical Devonian fossils are plentiful in the lower limestone which forms the block of the top of Roche Miette.

**Silurian.**—Shaly beds at the foot of Roche Miette may possibly belong to this age, but no fossils except species of *Stromatopora* have been found in them.

**Cambrian.**—Near the base of the series forming the mass of Roche Miette, a yellow band is exposed near the fault line which separates the lower rocks from the Cretaceous. In this yellow band the following trilobites have been collected:—*Crepicephalus iowensis, Ptychoparia affinis* and *P. wisconsinensis.*

Miles and Kilometres.

1,001 m. 1,611 km. **Pocahontas**—Altitude 3,282 ft. (1,000 m.). This station is opposite the Cretaceous portion of the outer fault block mentioned above. The Cretaceous beds, however, are not well exposed. A conglomerate band is easily traced on the opposite bank of the river, where it is seen in the fold which traverses the coal field. The coal seams here are above the conglomerate band and are mined in the western trough at this station. The mine entry is on the strike of a 10-foot (3 m.) seam.

1,027 m. 1,652 km. **Fitzhugh**—Altitude 3,457 ft. (1,057 m.). The mountains between Rocky and Snaring rivers are of the block type and are built of Devonian and Carboniferous limestone. The line of fault separating the younger ranges from a wide block which has evidently suffered a much greater upthrust, is passed before reaching Fitzhugh, a new town on the site of an old trading post established by the Northwest Trading Company in 1881 but long since abandoned. The throw of this fault is measured in thousands of feet, since the highest beds remaining in this block were beneath the limestone of the outer ranges. The structure to the west is somewhat similar to that at the summit on the Kicking Horse pass to the south. The valley of Miette river is denuded on the line of a local sharp fold or break.

1,044 m. 1,790 km. **Yellowhead**—Altitude 3,724 ft. (1,135 m.). The rocks exposed along the Miette river are a coarse quartzite and fine-grained conglomerates, which have been in places squeezed out to show schistose structure. Interbedded with these are greenish grey slates, and beneath, a few small exposures show dark argillites and thin-bedded calcareous sandstones.

Yellowhead mountain to the north shows, above the conglomerates and quartzites of the


Geological Survey, Canada

Route map between **Edson** and **Tête-Jaune**

Miles: 5 0 10 20 30 40

Kilometres: 5 0 10 20 30 40 50 60

Athabaska river and Outer range, Rocky mountains.

Jasper lake, Athabaska river from Roche Miette.

Miles and Kilometres.

lower slopes, a series of yellowish weathering crystalline dolomites which probably represent the Castle mountain series of the Laggan section to the south.

Fraser river is incised in the rocks of the lower part of these Cambrian sediments, and the mountains to the west seem to have little of the upper series on their summits. The structure of the mountains at the watershed is that of a shallow syncline of the coarse grained siliceous detrital matter, their lower slopes showing finer grained deposits of the Bow River series, while their summits preserve the dolomites of the Castle Mountain series.

1,079 m. **Mount Robson station**—Altitude 3,106 ft.
1,736 km. (947 m.). Mount Robson, viewed from the Fraser valley, towers high above the neighbouring mountains. Its beds are flat lying and show a section of nearly 10,000 feet of strata. These strata form the subject of a special enquiry by C. D. Walcott of the Smithsonian Institution.

1,095 m. **Tete Jaune**—Altitude 2,400 ft. (731·5 m.).
1,762 km.

## TOFIELD TO WINNIPEG.

### Introduction.

Tofield is 752 miles (1,209 km.) west of Winnipeg and stands at an elevation of 2,289 feet (697 m.) above sea level.

Between Tofield and Winnipeg the railway traverses a rolling or level prairie country underlain by horizontal or gently inclined Cretaceous and Palæozoic rocks. The following are the formations represented:—

Cretaceous { Edmonton series.<br>Belly River series.<br>Pierre shales.

Devonian.
Silurian.
Ordovician.

The country generally is so covered by a veneer of glacial drift that accurate boundaries between geological series can rarely be laid down. The Edmonton series ex-

Mount Robson from Grand Forks, Fraser river.

tends as far east as Ryley. From this point to Oban, the country is underlain by the Belly River series. The Eagle hills in the vicinity of Oban, may be topped by a slight thickness of Tertiary rocks. The Pierre shales extend from Oban to east of Caye. They are subdivided into the upper or Odanah and the lower or Millwood shales, the latter being very fossiliferous in the vicinity of Uno.

From Caye station eastward to Winnipeg and beyond, the Devonian, Silurian and Ordovician rocks are buried under the silts forming the bottom of glacial Lake Agassiz.

Between the east border of the Eagle hills and Young station, the railway traverses the bottom of glacial Lake Saskatchewan, a probable contemporary of Lake Agassiz. The lake was comparatively short lived, as evidenced by the absence of well marked terraces or beaches.

## Annotated Guide.

Miles and Kilometres.

752 m. 1,209 km. **Tofield**—Altitude 2,289 ft. (697 m.). The Edmonton series of clays dips to the west and may extend east to Ryley. Beyond Ryley the surface is covered by drift containing considerable sand derived from the Belly River series probably exposed east of Bruce.

703 m. 1,131 km. **Phillips**—Altitude 2,294 ft. (695 m.). Just east of Phillips the cuttings in the drift indicate the underlying sandy deposits. From here to Kinsella, boulder clay predominates, and the surface of the country is irregularly hilly.

678 m. 1,090 km. **Hawkins**—Altitude 2,126 ft. (647 m.). Several heavy cuts on the north side of Grattan creek show a section in the Belly River series consisting, in descending series, of light yellow sandstones with occasional brown streaks containing plant remains accompanied in some places by thin seams of lignite, greyish green shaly sands with brown ironstone nodules. In the valley of Battle river, a harder sandstone outcrops at a lower horizon and forms a slight bench on both sides of the valley.

667 m. 1 075 km. **Wainwright**—Altitude 2,213 ft. (673·4 m.). The underlying rocks are mostly of a sandy nature similar to those at Battle River crossing.


Relief map of the Great Plains.

Miles and Kilometres.

The surface drift is consequently sandy in character, and true sections are not seen until Manitou lake is reached.

South of the track at Wainwright the Canadian government has reserved nearly 144 square miles (37,762 hectares) for the maintenance of a herd of 1,217 bison (1912) commonly known as buffalo. The experiment appears to be successful and the herd is increasing; 220 calves are reported for 1912.

618 m.
994·4 km.

**Zumbro**—Altitude 2,051 ft. (625 m.). Between Zumbro and Yonker the railway follows the south shore of Manitou lake. The cut banks seen in the distance consist of the light coloured sands of the upper portion of the Belly River series. The basin is part of a former drainage channel into which several minor channels converge.

585 m.
941 km.

**Unity**—Altitude 2,087 ft. (636 m.). From Vera to Unity the railway traverses an old channel leading to Manitou lake, narrowing to Unity, where the general prairie level is gained. The plateau marks the approximate top of the Belly River series, the terrace lying to the north being probably underlain by Pierre shales. From Unity the railway runs along the foot of a slight escarpment which marks the northern edge of the Belly River rocks, that occasional cuts show to consist mostly of yellow sands.

569 m.
915·5 km.

**Scott**—Altitude 2,159 ft. (660) m.). South of Scott an old drainage channel marks the extreme end of the Eagle Hill creek drainage basin. Eastwards between Reford and Coblentz the cuttings show heavy deposits of boulder clay.

535 m.
861 km.

**Oban**—Altitude 2,120 ft. (646 m.). Two miles (3·2 km.) west of Oban dark shales outcrop and probably lie above the Belly River. From Oban eastwards to Mead, the country is rolling and constitutes the Eagle Hill belt, possibly underlain by Tertiary rocks. East of Mead the surface is very uniform and is underlain by sandy shales which suggest a

Miles and Kilometres.

light veneer of lower Tertiary continuing for some distance to the east. This plain is supposed to have been a glacial lake basin, known as Lake Saskatchewan, occupying part of the valleys of the North and South Saskatchewan and blocked or dammed to the northeast by the retreating Keewatin ice sheet. The existence of this lake, as inferred from the silts covering the surface, was not of long duration, since no strongly marked beaches are apparent. Milepost 478 marks the western edge of the flat country west of the Saskatchewan valley and may also mark the western limit of the glacial lake at its lowest stage in this latitude.

467 m. 751·4 km. **Saskatoon**—Altitude 1,665 ft. (507 m.). Saskatoon is situated on both sides of the Saskatchewan valley. Eastwards to Young, the country is flat with little evidence to show the character of the underlying rocks. The few cuttings show sandy clay with very few boulders.

422 m. 679 km. **Young**—Altitude 1,714 ft. (522 m.). Near the station there appears to be a possible outlet valley to the southeast for the glacial Lake Saskatchewan. This valley appears to join the deep valley occupied by Lost Mountain lake, which is a tributary of the Qu'Appelle. The difference in elevation between Young and Lost Mountain lake is 118 feet (35·8 m.) and if the drainage was southwards at any time it was of short duration otherwise it would be expected that the valley of Lost Mountain would have deepened itself further to the north.

The deep valley of the tributary of the Qu'Appelle lying west of the foot of Lost Mountain lake and extending to the elbow of the South Saskatchewan, marks the old main channel of the latter river when it flowed eastwards through the length of the present Qu'Appelle valley.

408 m. 656 km. **Watrous**—Altitude 1, 781 ft. (543 m.). The position of the front of the Keewatin ice sheet during a pause or a series of advances and

Miles and Kilometres.

retreats is indicated between Young and Watrous, a distance of 14 miles (22·4 km.), by a series of morainic hills of boulder clay of drumlin-like form with a trend to the northeast.

372 m. 598 km. **Semans**—Altitude 1,844 ft. (562 m.). At Semans the bare plains are left behind and hilly country is entered which is fairly well wooded. The surface veneer is more or less of boulder clay and is rather thin. At Punnichy 20 miles (32 km.) to the east, the exposures appear to be the top of the Pierre shales or the Foxhill from the yellow sandy clays which outcrop near Touchwood station. Just west of Touchwood, the railway follows a series of lake basins that appear to be in an old and abandoned valley. The country is fairly open to Melville.

265 m. 426 km. **Waldron**—Alt. 1,739 ft. (530 m.). Waldron lies near the edge of the wooded country which the railway enters in part and in part follows the southern edge. Welby is the last station in Saskatchewan and is situated on the plateau above the Qu'Appelle. From here the line descends along the side of the valley to the bottom land of the Assiniboine river passing Lazare at the confluence of the two streams.

186 m. 299 km. **Uno**—Altitude 1,370 ft. (427 m.). One mile (1·6 km.) east of Uno station, the Millwood shales outcrop along the side of the Assiniboine valley and continue east to the crossing of Birdtail creek. The shales are dark grey in colour with ironstone nodules referred to the lower part of the Pierre.[a]

The fossiliferous beds contain *Baculites compressus, Pteria linguiformis, Inoceramus tenuilineatus, Inoceramus sagensis, Nucula, Lucina occidentalis, Entalis paupercula, Scaphites nodosus, Hylobiites cretaceus* and some 15 species of *Radiolaria.*

**Arrow River**—A short distance east of the station several cuttings show a light grey shale which is probably the Odanah.

[a] Tyrrell, J. B., Geol. Surv. of Can., Vol. V, 1890-91, p. 213 E.

Miles and Kilometres.

**Rivers**—The railway crosses the terraced valley of the Little Saskatchewan.

121 m. 195 km. **Justice**—Altitude 1,430 ft. (436 m.). The boulder clay is overlain by lake and delta silts marking the western limits and high water level of the glacial Lake Agassiz. At Ingelow eight miles (12·8 km.) to the east the first beach or evidence of shore line appears.

54 m. 87 km. **Portage la Prairie**—Altitude 850 ft. (259 m.). The railway here traverses the bottom lands of glacial Lake Agassiz and continues to Winnipeg.

0 m. 0 km. **Winnipeg**—

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## WINNIPEG TO COCHRANE VIA NATIONAL TRANSCONTINENTAL RAILWAY.

### INTRODUCTION.

BY

W. H. Collins and M. E. Wilson.

The distance from Winnipeg to Cochrane by way of the National Transcontinental railway is 780 miles (1,255 km.) The route lies over flat-lying Palæozoic sediments of the interior plains region for the first 50 miles (80 km.), and then enters upon the Pre-Cambrian shield, which is continuous for the remainder of the distance. For 55 miles (88 km.) east of Winnipeg, the Palæozoic beds and their junction with the Pre-Cambrian are completely concealed by the alluvial deposits of glacial Lake Agassiz. Again near Lake Nipigon the Pre-Cambrian bed rock is largely hidden beneath stratified sand and clay laid down in a great bay of the extinct glacial Lake Warren which formerly occupied the present basin of Lake Nipigon. And in the region lying between Kenogami river and Cochrane, the Pre-Cambrian rock surface is almost completely buried beneath the lacustrine clay of Lake Ojibway.

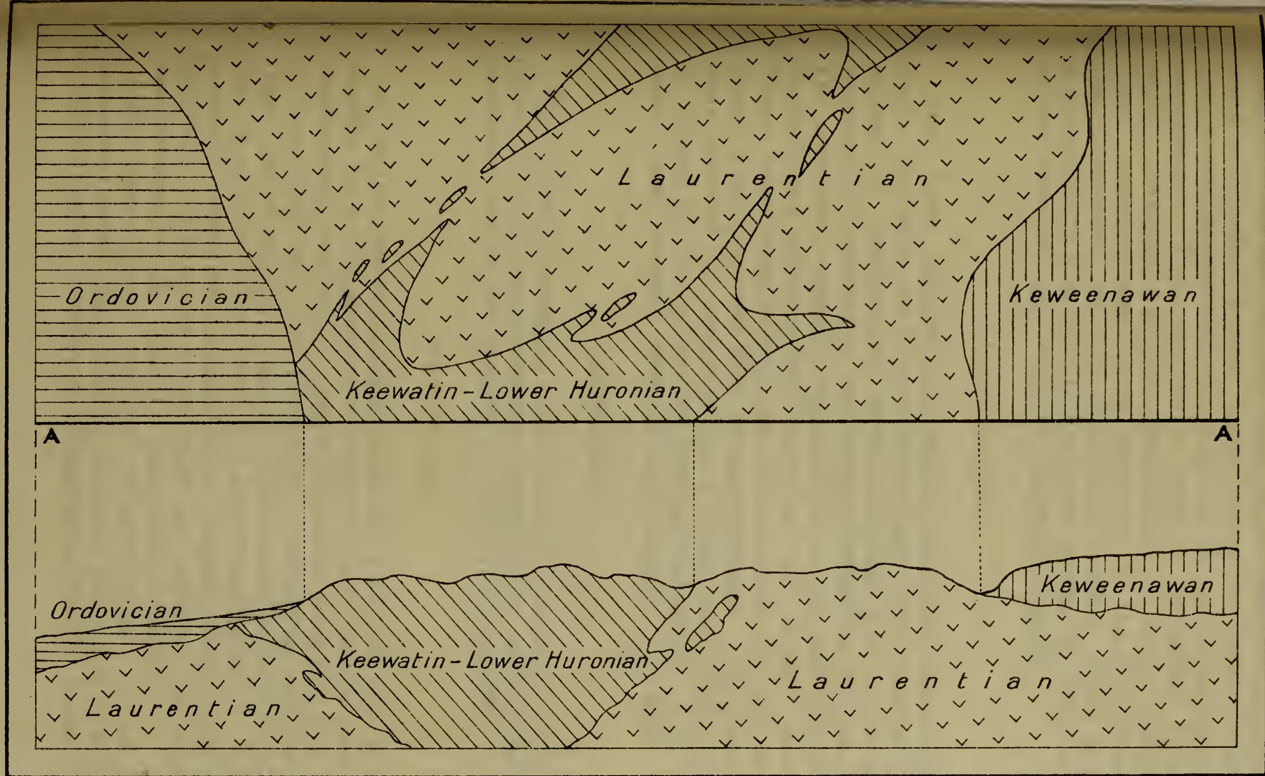
The rocks of this region may be separated into five main groups, distinct from one another in age, lithological character, and in their structural relationships as expressed in the accompanying diagram.

### KEEWATIN AND LOWER HURONIAN

This oldest group is a highly metamorphosed complex consisting of a variety of acid and basic eruptives and minor amounts of banded iron formation (Keewatin); and a younger sedimentary series of conglomerate, greywacke, slate with local iron formation phases, and associated eruptives (Lower Huronian). These have endured at least one orogenic disturbance which folded them and converted them into highly inclined schists. Granite batholiths, which were intruded at probably the same period, have further metamorphosed them near their contacts to crystalline, hornblende gneisses, amphibolites, mica schists, etc. But, away from the batholithic contacts, where metamorphism has been less intense, the ellipsoidal, amygdaloidal, and other structures of the Keewatin volcanics and the stratification of the Huronian sediments are still sometimes recognizable. An unconformity exists between the Keewatin and Lower Huronian, but so profoundly has it been modified by these metamorphic changes that its importance can not be satisfactorily estimated; in fact it is usually difficult to recognize. In later Pre-Cambrian time, protracted erosion unroofed the granite batholiths and removed all except the synclinal portions of this folded Keewatin-Lower Huronian group leaving it distributed much as it is today [**7** and **23**].

### LAURENTIAN.

This term is applied broadly to all granites and gneisses in the region. As indicated in the diagram, the Keewatin-Lower Huronian areas form a rude meshwork, the interspaces of which are occupied by more or less distinct, oval areas of gneiss and granite, that probably represent individual batholithic domes. These rocks are dominantly granodiorites, though granites and syenites are also present. A gneissic texture is more common than a granitic one, particularly in granodiorite facies. Also, near contacts with the Keewatin-Lower Huronian complex, the gneiss contains a varying quantity of these older materials which have been stoped off and floated out into the granite magma while the latter was still plastic. The distribution and character of these inclusions would imply that the gneissic structure of the enclosing rock also was




Geological Survey, Canada.

*Figure I. Diagram showing geological relationships in the region between* ***Lake Nipigon*** *and* ***Winnipeg****, with a diagrammatic* ***Section*** *along the* ***Line A-A***

developed during a state of plasticity. Some of the inclusions retain their angular shapes, some are rounded, and others have been drawn out into thin ribbons by magmatic movements. They are always notably crystalline, being chiefly hornblende gneiss, amphibolite, or biotite gneiss. The "transition zone" thus developed in the Laurentian near its contacts with the older rocks varies in width from a few yards to five miles (8 km.) and merges by reduction of the inclusions into ordinary Laurentian gneiss.

### KEWEENAWAN.

Near Lake Nipigon the greatly dissected Keewatin-Lower Huronian and Laurentian surface is unconformably overlain by a sedimentary series consisting of a thin basal conglomerate, sandstone, and impure ferruginous dolomite. The dolomite is usually bright red in colour and contains disseminated gypsum and traces of salt crystal casts. These formations, which are Keweenawan in age, are almost flat-laying and little metamorphosed. They have been intruded by somewhat later dykes and thick sills of diabase similar to the ore-bearing diabases of Cobalt district and the south shore of Lake Superior [**7**; **12.**].

### ORDOVICIAN.

The eroded Laurentian surface of the western part of the region is also unconformably overlain by undisturbed sandstone and impure limestone of Ordovician age [**9**].

### PLEISTOCENE.

All of the preceding solid rocks are glaciated and are overlain by a thin mantle of unconsolidated gravel, sand, boulders and boulder clay, materials which were laid down in association with the Pleistocene continental glaciers. These glacial and fluvio-glacial deposits are in turn overlain, by stratified clay, sand and gravel deposited in the previously mentioned glacial lakes, Agassiz, Warren and Ojibway. All three of these lakes are believed to have been dammed on the north by the waning ice sheet.

Lake Agassiz was a vast body of water which extended throughout nearly the whole of southern Manitoba as well as the adjacent portion of Minnesota, North Dakota,

Manitoba and Saskatchewan. The total area covered by the lake during the various stages of its existence has been estimated to have been not less than 110,000 square miles (275,000 sq. km.). The deposits laid down in the deeper parts of the lake consist of a thin layer of clayey silt but along the shore, gravel and sand were built up to a thickness of—in some of the deltas—50 to 200 feet (15 to 60 m.) [**20; 21**].

The post-glacial deposits around Lake Nipigon were laid down in Lake Warren, the largest of the lakes which occupied the upper part of the St.Lawrence basin following the retreat of the Labradorean ice sheet. A northern bay of this lake covered a wide area of country in the vicinity of Lake Nipigon. The deposits from this bay of Lake Warren are found along the railway between Wagaming and Ombabika bay, a distance of 30 miles (48 km.). They consist of stratified sand underlain by clay and have a thickness of approximately 100 feet (30 m.) (**6**) (**14**) (**22**).

The third area of lacustrine deposits traversed by the railway, were laid down from a lake which lay for the most part in the southern part of the James Bay basin but also extended across the St. Lawrence-Hudson Bay divide into the Ottawa basin, for, in northwestern Quebec, the lacustrine clays have been traced continuously from Lake Timiskaming to points north of the divide. For this body of water the name Lake Ojibway has been suggested by A.P. Coleman. The areal extent of its deposits have not yet been precisely ascertained but they are known to occur throughout an area of at least 50,000 square miles (125,000 sq. km.). They occur almost continuously along the National Transcontinental railway from the crossing of the Kenogami river to Cochrane a distance of 320 miles (515 km.), and to the eastward of Cochrane for a distance of 210 miles (350 km.),—a total extent from east to west along the railway of 530 miles (853 km) (**9**). They consist largely of uniformily stratified clays or clay and sand and for that reason the region throughout which they occur is known generally as the "clay belt." Their thickness is nowhere very great the maximum recorded in the cuts along the National Transcontinental railway being only 26 feet (7·9 m.). [**1, 2, 3, 5, 10, 11, 13, 26, 27**].

TABULAR RESUME.

The major events in the geological history of this region so far as they have been interpreted may be summarized as follows:—

| Time. | Event. |
|---|---|
| Keewatin | Protracted vulcanism, with minor deposition of banded iron formation and other obscure sediments. |
| | Unconformity, erosion and probably batholithic intrusion. |
| Lower Huronian | Deposition of conglomerate, greywacke and slate with contemporaneous vulcanism. |
| Laurentian | Orogenic disturbance of Keewatin and Lower Huronian rocks, with intrusion of granite batholiths. |
| | Great unconformity; peneplanation. |
| Keweenawan | Deposition of conglomerate, sandstone and dolomite; later intrusion of diabase sills. |
| Ordovician | Marine submergence and deposition of impure limestone in the western part of the region. |
| | Unconformity. |
| Pleistocene | Glaciation, formation of glacial lakes, ice retreat. |

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## ANNOTATED GUIDE.

### Winnipeg to Nipigon.

BY

W. H. Collins.

Miles and Kilometres.

0 m.
0 km.

**Winnipeg**—Altitude 763 ft. (232·7 m.). For 55 miles (88 km.) east of Winnipeg the railway pursues a direct course across flat prairie country, almost treeless for the first 25 miles (40·2 km.), but becoming more and more thickly forested as the Pre-Cambrain shield is approached. This is the bed of glacial Lake Agassiz. The slight amount of excavation required by railway construction in this alluvial plain, whose local relief does not exceed 20 feet (6·5 m.), nowhere exposes the Ordovician bed rock. It only shows from one to four feet

Miles and Kilometres.

(3 to 1·2 m.) of black vegetable mould overlying poorly assorted, boulder clay or yellow mud.

Red river is crossed at the outskirts of Winnipeg.

5·4 m.
8·6 km. **Transcona**—Altitude 758 ft. (231·1 m.). The workshops and terminal yards of the Grand Trunk Pacific railway are situated at Transcona.

31·0 m.
49·6 km. **Vivian**—Altitude 891·5 ft. (271·8 m.). The monotonous flatness of the prairie is broken just west of Vivian by a low, flat-topped ridge through which the railway has made a cut 12 feet (3·9 m.) deep and 150 feet (45 m.) long. The gravel and sand composing this ridge are cross-bedded, and the larger pebbles have the the flattened shapes of beach shingle. While it has not been more carefully investigated and its extent north and south of the railway is unknown, this ridge is thought to be an old Lake Agassiz beach.

56·2 m.
89·9 km. **Elma**—Altitude 921 ft. (280·9 m.). The first outcrop of Laurentian gneiss is seen just west of milepost 56.

65·3 m.
104·5 km. **Hoctor**—Altitude 999 ft. (304·7 m.). Between milepost 60 and Hoctor the flat alluvial lake bottom gives place to the rocky Pre-Cambrian region. Low masses of rock protrude more and more frequently through the flat swamps and muskegs, and occasional lakes, so characteristic a feature of the Pre-Cambrian region, appear. The rocks exposed here and for the the next 165 miles (274 km.) are all Laurentian gneisses or "transition zone" mixtures of Laurentian gneiss and Keewatin inclusions.

The Canadian Pacific railway is crossed at ·65 miles (1·0 km.) east of milepost 69.

99·3 m.
158·9 km. **Malachi**—1,082 ft. (330· m.). Between White and Malachi, the gneiss contains a large proportion of Keewatin inclusions ranging in form from angular blocks to slender ribbons. From milepost 80 to milepost 84 the proportion of Keewatin material (hornblende gneiss) increases to 75 per cent and is traversed only by dykes and stringers of Laurentian granite and

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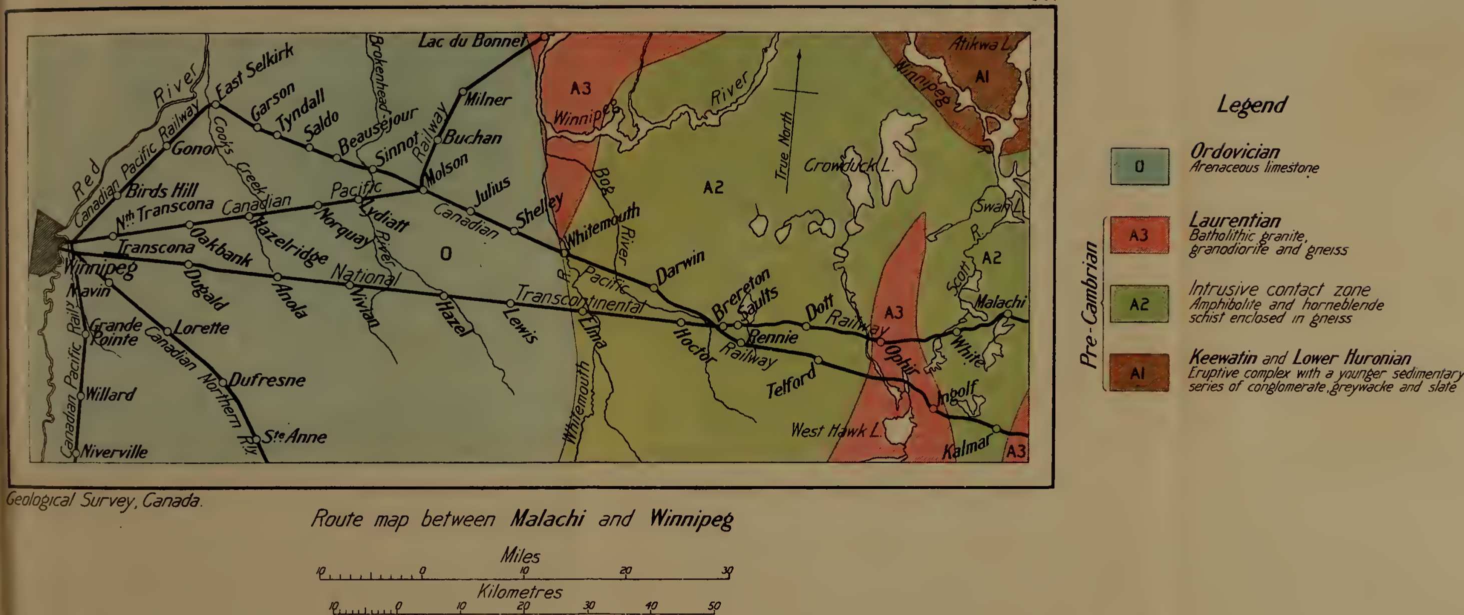
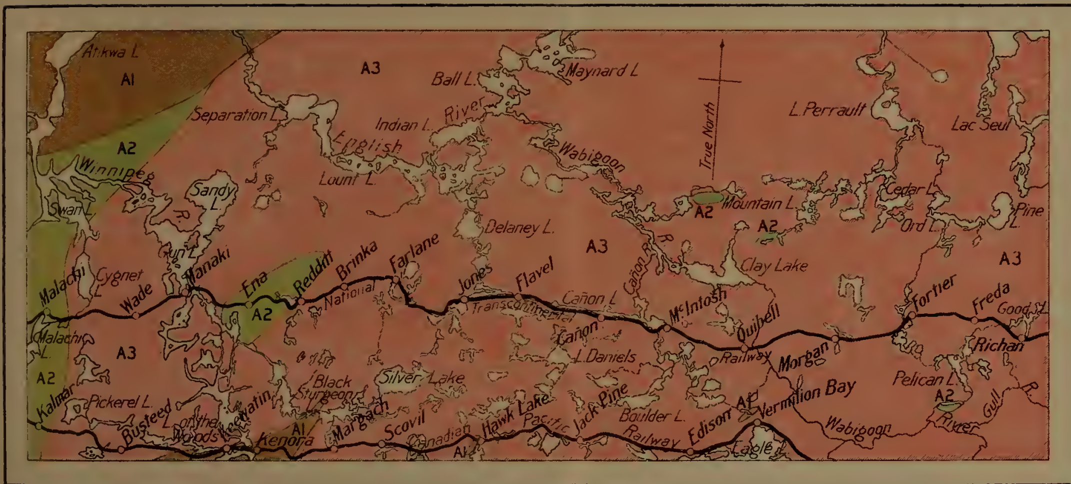



Geological Survey, Canada.

Route map between **Malachi** and **Winnipeg**

C4.




Geological Survey, Canada.

Route map between Richan and Malachi

Miles

10 0 10 20 30

Kilometres

10 0 10 20 30 40 50

## Legend

Pre-Cambrian

| | | |
|---|---|---|
| A3 | **Laurentian** | Batholithic granite, granodiorite and gneiss |
| A2 | **Intrusive contact zone** | Amphibolite and horneblende schist enclosed in gneiss |
| A1 | **Keewatin and Lower Huronian** | Eruptive complex with a younger sedimentary series of conglomerate, greywacke and slate |

Miles and Kilometres.

pegmatite. The various stages in magmatic stoping are well illustrated in this interval.

115·2 m.
184·3 km. **Minaki**—Altitude 1,048 ft. (319·6 m.). Winnipeg river, the largest stream crossed by this section of the railway, is crossed just east of milepost 115.

129·4 m.
207 km. **Redditt**—Altitude 1,071 ft. (326·6 m.). Between milepost 149 and 152 the gneiss has been sliced into thin parallel plates from an inch (2·5 cm.) to several feet (1 m.) in thickness, apparently as a result of yielding to stresses.

168·9 m.
271·9 km. **McIntosh**—Altitude 1,228 ft. (374·5 m.). From milepost 154 to milepost 169 the railway follows the south shore of Cañon lake, a typical example of the rocky lakes characteristic of the Pre-Cambrian region. The country here is unusually rugged and a number of short tunnels occur on the railway.

177·4 m.
283·8 km. **Quibell**—Altitude 1,178 ft. (359·2 m.). During Glacial time portions of Wabigoon River valley were probably ponded and received deposits of stratified clay similar to those laid down in the larger glacial lakes. This lacustrine deposit first appears on the railway near milepost 172, where the boulder clay changes in somewhat transitional manner to stratified clay. From this point to milepost 185 the finely laminated clay is almost continuous; between mile posts 175 and 181 it forms a comparatively level plain, resembling, on a small scale, the prairie region of the west.

206·4 m.
330·2 km. **Richan**—Altitude 1,285 ft. (391·9 m.). Laurentian gneiss is again abundantly exposed from the eastern edge of this clay deposit to milepost 224, where it becomes obscured by glacial materials.

At ·4 mile (·6 km.) east of milepost 223 a deep cut has been made in a hill of imperfectly stratified sand and gravel.

231·7 m.
470·7 km. **Webster**—1,234 ft. (376·3 m.). Between mileposts 217 and 234 the route skirts the northern margin of a terminal moraine and outwash deposit which extends southward. The country north of the railway is scantily clad

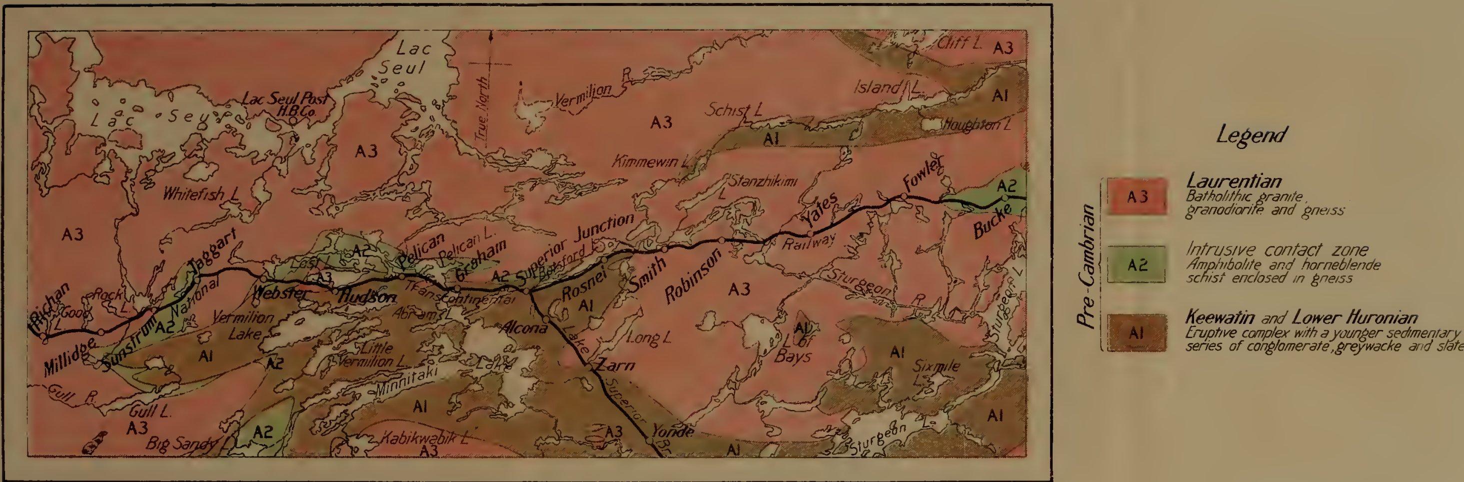
Miles and Kilometres.

with soil. As the train approaches milepost 232 a good view is obtained of an esker-like ridge laid down apparently by a southward flowing englacial stream. The forest in this vicinity has been fire-swept, and the sinuous course of the ridge may be easily observed for nearly a mile to the north. Farthest away it is a low ridge of coarse boulders, but, approaching the railway, it grades successively into gravel and sand, becoming higher and broader at the same time. Where the railway cuts through it to a depth of 40 feet (12·2 m.), it consists of convexly bedded and cross-bedded sands, through which are scattered occasional large boulders. South of the track it merges into the terminal moraine already mentioned. The course of this glacial stream was evidently independent of the topography of the ice-covered country, for the deposit which marks it winds up a steep slope to the railway. A small kettle lake on the south side of the railway can be seen from the same point.

Schists of the Keewatin-Lower Huronian group are seen first near milepost 236. For 29 miles (46·4 km.) eastward from this point, the railway runs near the northern margin of a large area of these rocks, crossing at irregular intervals tongues of Laurentian, which are intrusive into it from the north. But, for most of this distance, the rocks are poorly exposed.

Intrusive dykes and tongues of granite are especially common between mileposts 236 and 250. Ordinarily the Laurentian is strongly gneissic at its contacts with the Keewatin, and includes a large proportion of fragments of the older formation. Less frequently the magma seems to have been more fluid and crystallized as massive granite, nearly free from xenoliths. The contacts in this vicinity are of the latter type. At ·25 mile (·4 km.) east of milepost 249, for example, granite is in sharp contact with an overarching chloritic schist. The granite in this and similar cases approximates more or less closely in composition to a true

C4.




Geological Survey, Canada.

Route map between Bucke and Richan

Miles

10 0 10 20 30

Kilometres

10 0 10 20 30 40 50

Miles and Kilometres.

granite; a granodioritic composition appears to be more characteristic of gneissic phases of the Laurentian, which contain partly assimilated Keewatin inclusions.

The spur leading southward from the main line near Pelican connects with a mine on Vermilion lake, where a large vein of pyrite is being developed.

252 m. **Graham**—Altitude 1,189·4 ft. (362·6 m.).
403·2 km. Between Graham and Superior the schists are covered by stratified clay similiar to that seen in Wabigoon valley and probably laid down in a former expansion of Sturgeon river. The rocky banks farther upstream show numerous large potholes from 10 to 15 feet (3 – 5 metres) above the present level of the river, indicating its former volume to have been much larger than the present one. A narrow belt of closely folded Lower Huronian conglomerate and greywacke follows the course of Sturgeon river, but is hidden beneath the stratified clay, where the railway crosses the river just west of Superior.

258·4 m. **Superior**—Altitude 1,190 ft. (362·9 m.).
413·4 km. Keewatin schists give place to the Laurentian gneiss near Rosnel. Keewatin rocks are once more traver-

267·9 m. **Rosnel**—Alt. 1,180 ft. (359·9m.) sed in the
428·6 km. next 51 miles (81·6 km.), but there is little of geological interest to be seen in this distance. At the Laurentian-Keewatin contact, 3·7 miles (5·9 km.) east of Staunton, the schists are derived from acid eruptives and exhibit much less contact metamorphic effects than is the case with basic materials where so close to the Laurentian intrusives.

The greatest elevation (1,457 ft. 444·1 m.) on the railway between Winnipeg and Lake Nipigon is attained 3 miles (4·8 km.) east of Bucke.

312·4 m. **Bucke**—Altitude 1,401 ft. (427·3 m.). The
499·8 km. first erosion remnant of Keweenawan diabase is passed 2 miles (3·2 km.) east of Harvey. Such vestiges of diabase sills become larger and

Miles and Kilometres.

more numerous as the main Keweenawan area around Lake Nipigon is approached. They have a pronounced columnar and parallel jointing, which gives rise in them to a much more precipitous relief than is seen in the Laurentian.

334·9 m.
535·8 km.

**Allen Water**—Altitude 1,332 ft. (4,062 m.). Between Kawa and Allen Water river, the gneiss contains numerous angular and ribbon-like inclusions of hornblende gneiss, derived from the Keewatin.

About a mile and a half (2·4 km.) west of Kawa, Keweenawan diabase may be seen lying directly upon Laurentian gneiss. At this point, on the north side of the railway, a cliff of diabase rises abruptly from a comparatively flat Laurentian floor.

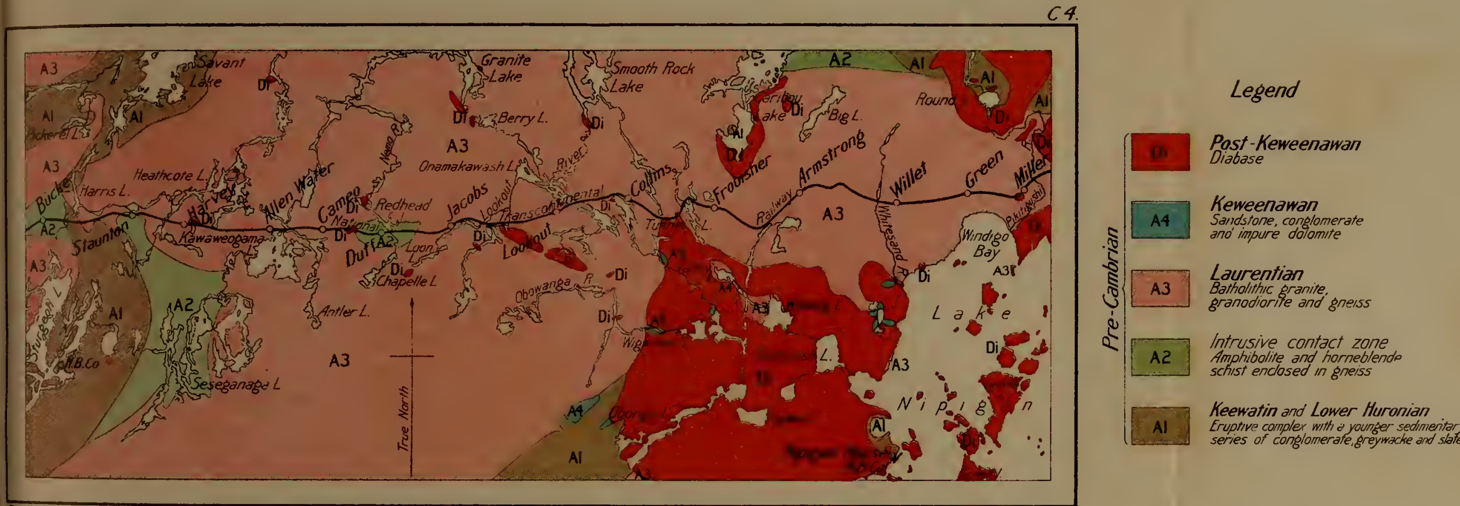
362·4 m.
579·8 km.

**Ogoki**—Altitude 1,273 ft. (388·2 m.). From Cameo to Ogoki the forest has been burned, the gneiss is almost completely bare of soil, and the country is excessively bleak-looking. Between Kawa and Jacobs, however, a number of conspicuous gravel hills rise directly from this bare rock surface.

The precipitous topography characteristic of the Keweenawan sills is exemplified between Jacobs and Ogoki, where the railway skirts a small but rugged canyon carved in this formation.

391 m.
625·6 km.

**Armstrong**—Altitude 1,113 ft. (339·4 m.). The Laurentian gneiss disappears under a mantle of boulder clay four miles (6·4 km.) east of Armstrong and, from this point to Lake Nipigon, solid rocks are infrequently exposed. Low sand hills and muskegs, intersected by sluggish creeks, take the place of the hummocky rock surface and rock-bound lakes. Near Wagaming the boulder clay merges into a comparatively flat plain underlain by the stratified sand and clay of glacial Lake Warren. There are few excavations along the railway in which these lacustrine deposits are favourably exposed, but natural sections are exposed by the streams flowing toward Lake Nipigon, which are rapidly deepening their channels




Geological Survey, Canada.

Route map between Lake Nipigon and Bucke

Miles

10 0 10 20 30

Kilometres

10 0 10 20 30 40 50

Miles and Kilometres.

toward the underlying Pre-Cambrian rock surfaces. Just west of Willet, Mud river. altitude 904 ft., (275·5 m.) has cut a channel 60 feet (17·8 m.) deep in stratified silt and clay. [4].

421 m.
673·6 km. **Ferland**—Altitude 970 ft. (295·8 m.) The only important rock exposure in this vicinity is a monadnock-like hill of Keweenawan diabase, known as Haystack mountain, which projects through the lacustrine deposits near Willet.

## ANNOTATED GUIDE—(Continued.)

BY

A. G. BURROWS.

Between Lake Nipigon and Iroquois Falls the underlying bed rock is largely covered by glacial and post-glacial deposits. The number of outcrops, however, have been considerably increased by excavations made during the construction of the railways.

The solid rocks outcropping between Lake Nipigon and Iroquois Falls consist chiefly of biotite and hornblende granite, granodiorite and diorite. These are all more or less foliated and frequently intruded by numerous dykes of pegmatite and aplite. They belong to the pre-Cambrian granite-diorite complex generally called Laurentian.

416 m.
660 km.
"*Dist.E."
215 m.
346 km. **Pikitigushi river** — Altitude 898·4 ft. (272·4 m.). Two miles east of the crossing of Pikitigushi (Mud) river there is a N.-S. trending ridge of Keweenawan diabase which continues southward to form a very prominent peninsula on the north shore of Lake Nipigon, known as North Ombabika.

* The miles and kilometres given under districts refer to the distance from the easterly limit of the subdivisions into which the country along the National Transcontinental was divided for engineering purposes. Thus Cochrane lies 103 miles west of the eastern limit of District D.

Miles and Kilometres.

470·5 m. **St. Lawrence—Hudson Bay divide.** Alti-
762 km. tude 1,122 ft. (341·9 m.). Forty miles (64 km.) to the
"District east of Ombabika the railway crosses the height
E" of land between Lake Superior and Hudson
166·5 m. bay. The rivers to the east of this watershed
267 km. all flow into the Albany and Moose, two large
rivers, which have their outlet into James bay, the southern extremity of Hudson bay.

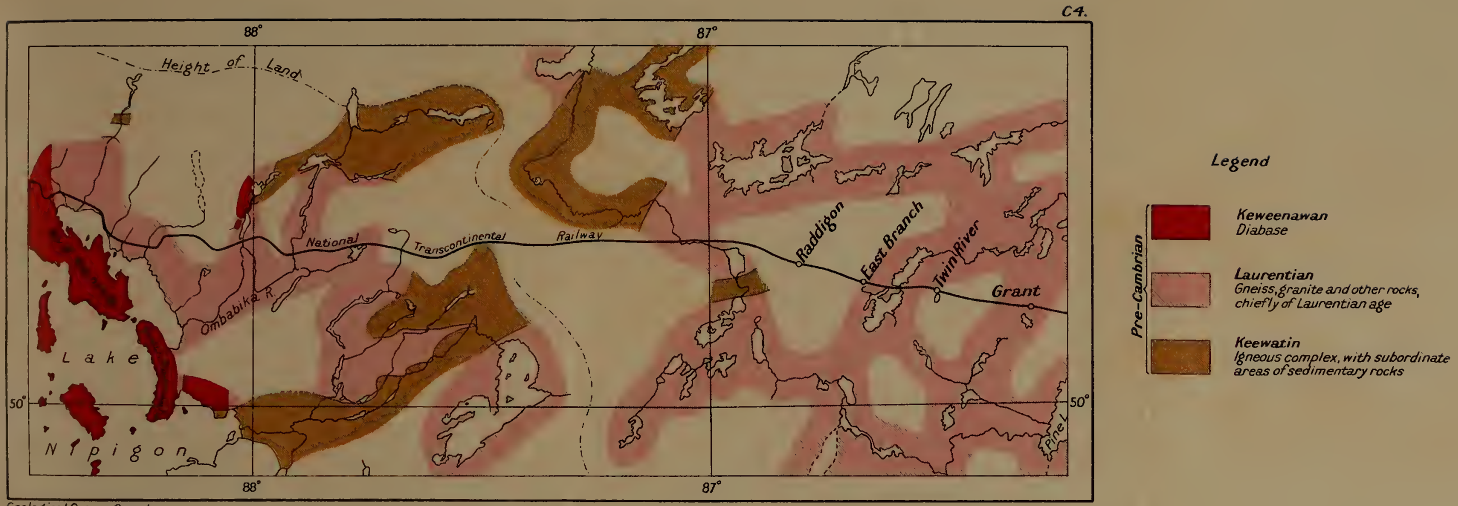
The bed rocks in the vicinity of the height of land belong to the Keewatin complex. The Pleistocene deposits are largely stratified sand, clays and gravel.

After crossing the height of land the railway enters upon the region underlain by the post-glacial lacustrine deposits of Lake Ojibway which is now generally known as the clay belt of northern Ontario and Quebec. There are many million acres of these lacustrine clays which afford an excellent soil for the growth of wheat and other cereals and a colonization movement to the region has begun. The provincial governments are assisting this movement by building numerous trunk roads to en-
570·5 m. able the settlers to gain access to their farms.

925 km. **Pagwachuan river**—Altitude 578 ft. (176 m.).
"District West of the Pagwachuan river there are several
E." outcrops of dark, banded, hornblende-biotite-
60·5 m. gneiss containing phenocrysts of red feldspar
97·3 km. up to two inches in length.

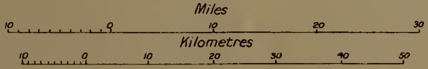
626 m. **Kabinakagami river**—Altitude 787·3 ft.
1,023 km. (239·9 m.). The railway crosses Kabinakagami
"District river at a rapid formed by a barrier of Lau-
E." rentian gneiss. Similar gneiss can also be seen
6 m. at the crossing of White, Skunk and Nagagami
10 km. rivers.

643·5 m. **Hearst**—Altitude 795 ft. (242 m.). Hearst,
1,055 km. situated two miles west of the crossing of
"District Mattawishquia river, is a divisional point on
D." the Transcontinental railway and the junction
232·5 m. point with the Algoma Central railway. The
347 km. town lies in the midst of a wide area of country
possessing an excellent soil for the growth of agricultural products.




Geological Survey, Canada

Route map between **Grant** and **Lake Nipigon**



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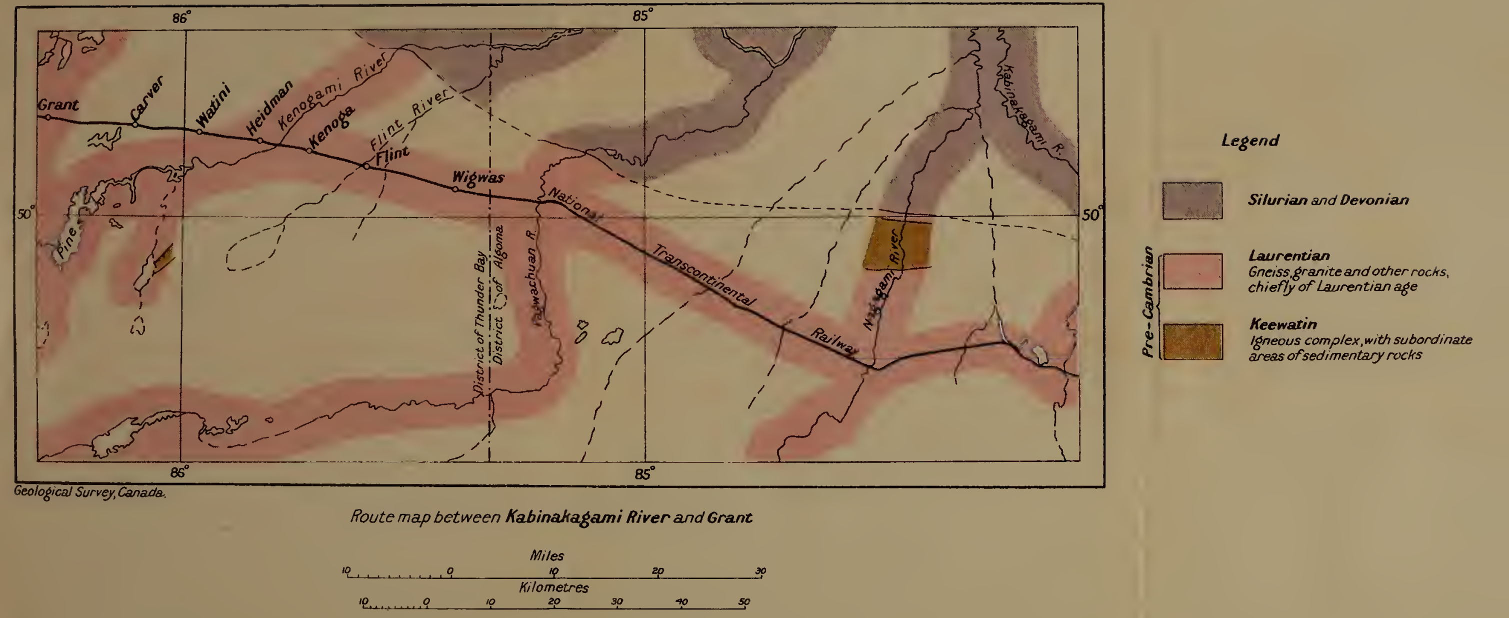
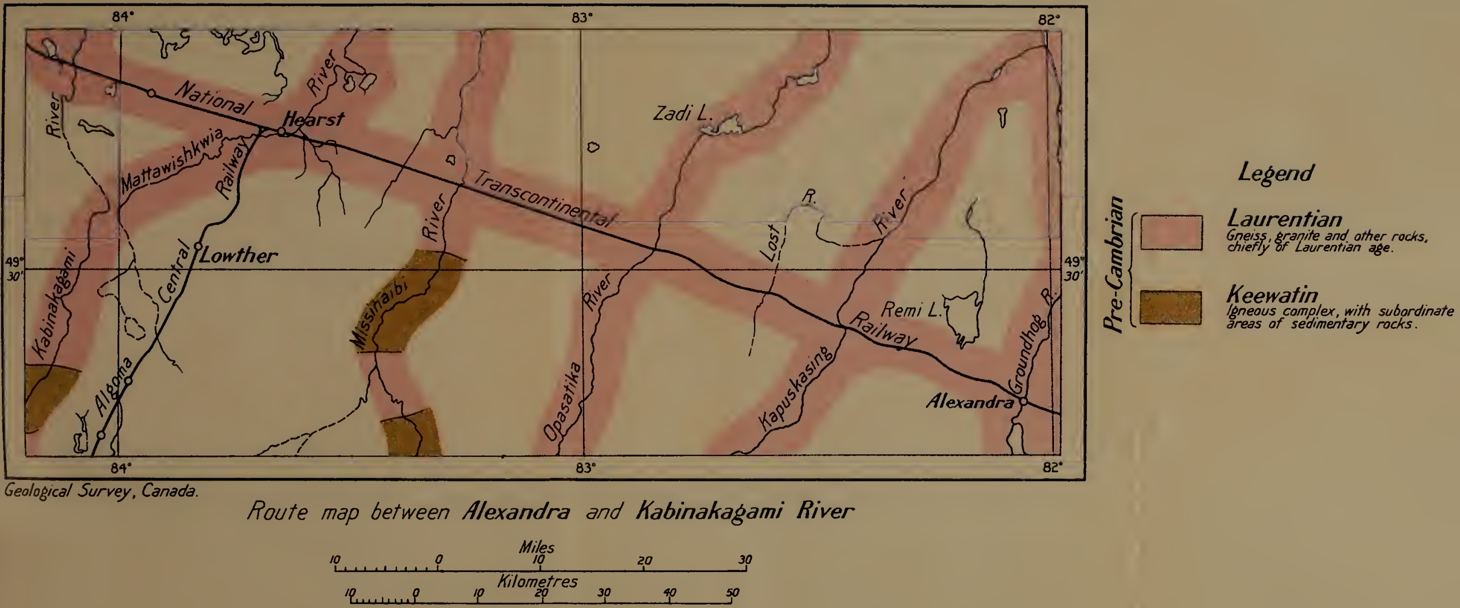



Geological Survey, Canada.

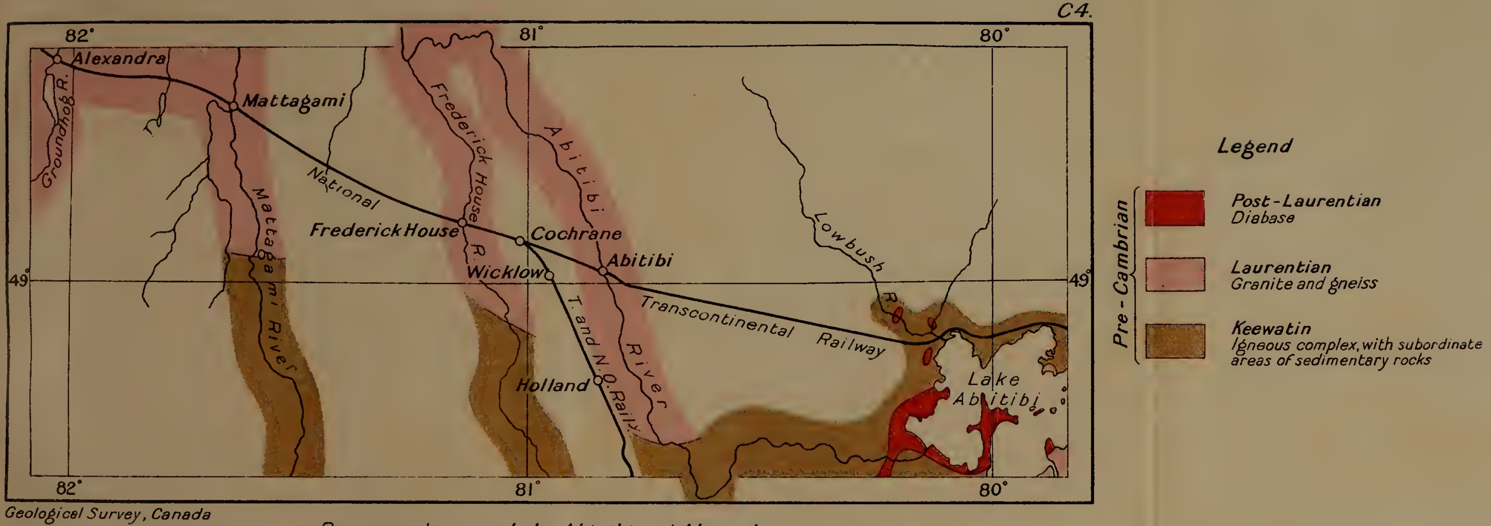
Route map between **Kabinakagami River** and **Grant**

C4.




Geological Survey, Canada.

Route map between **Alexandra** and **Kabinakagami River**




Route map between **Lake Abitibi** and **Alexandra**

Miles and Kilometres.

Three miles (4·8 km.) west of Hearst, grey, biotite-gneiss cut by dykes of light coloured, biotite-muscovite-pegmatite is exposed in a rock cut along the railway. The foliation of the gneiss strikes N. 35° E. The rock surface has been greatly polished by the continental glaciers, the direction of the ice movement, as indicated by the striae, being S. 30° E.

The southern limit of the broad belt of Palæozoic sediments which lie to the south and west of Hudson bay, occurs just 15 miles (24·2 km.) north of this point.

662·5 m.
1,066 km.
"District D."
213·5 m.
343 km.

**Missinaibi river.**—Laurentian gneiss is exposed at the crossing of the Missinaibi, which is one of the largest tributaries of Moose river and for two centuries the principal route used by the employees of the Hudson's Bay Company in travelling from Lake Superior to Hudson Bay.

699 m.
1,125 km.
"District D." 73 m.
278 km.

**Kapukasing river**—Kapukasing river is crossed at a waterfall formed by a barrier of mica-hornblende-gneiss which the river has encountered in cutting through the overlying drift.

722 m.
1,162 km.
"District D."
153·5 m.
246·9 km.

**Ground Hog river.**—Laurentian gneiss also occurs at the crossing of Ground Hog river. On the east side of this river the stratified clay laid down in lake Ojibway can be seen in section. Between Ground Hog and Mattagami rivers there are several exposures of Laurentian gneiss.

At mileage 730 (1,175 km.) a dyke of fresh diabase intrudes the Laurentian.

769 m.
1,398 km.
"District D."
103 m.
165 km.

**Cochrane**—Altitude 915 ft. (278·6m.). Cochrane is the present terminus of the Timiskaming and Northern Ontario railway and a divisional point on the National Transcontinental. It is also the centre of an agricultural district which is being taken up rapidly by settlers.

The Pre-Cambrian bed rock is not exposed at Cochrane but glacial deposits and a number of clear water kettle lakes may be seen.

T. & N. O. railway. Miles from North Bay.

253·1 m. 407 km. **Cochrane**—Altitude 915 ft. (278·6 m.). From Cochrane southward as far as mileage 229 (368 km.) there is a rather flat area of country which is underlain by clay and sand covered with a layer of peat.

224·8 m. 362 km. **Iroquois Falls**—Altitude 945 ft. (288 m.). North of Iroquois Falls there are ridges of stratified sand and gravel with many clear water kettle lakes.

Iroquois Falls is the junction point of the main line of the Timiskaming and Northern Ontario railway and the Porcupine branch.

For a description of the route from Iroquois Falls to Porcupine and Toronto and the ore deposits of this region see guide to Excursion A3 in Guide Book No. 6.

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GUIDE BOOK No. 10

# EXCURSIONS

IN

# Northern British Columbia and Yukon Territory and along the North Pacific Coast

(EXCURSIONS C 8 AND C 9.)

y

*ISSUED BY THE GEOLOGICAL SURVEY*

OTTAWA
Government Printing Bureau
1913

34883—1.

Gift of
Mary J. Lanier

# *ERRATA.*

## Guide Book No. 10.

PAGE.

3. In Contents, number "37" should be opposite "Yukon and Malaspina."
122. 5th line from top—for "Nunakak" read *Nunatak.*
124. 9th line in 3rd paragraph—for "Grillon" read *Crillon.*
125. 3rd line from bottom—for "John" read *Johns.*
126. Legend of photograph—for "on 1911" read *in 1911.*
127. 8th line from top—for "C. F. Wright" read *G. F. Wright.*
129. After first line in table—add *About 1814, Advance; Over 1 mile, W. Ogilvie.*
130. Substitute the following for the half of the table, below "Earthquake."

| | | | | |
|---|---|---|---|---|
| 1899 to 1906. | Retreat.... | 30,360 ft.... | 4,337 ft. . . | F. E. & C. W. Wright |
| 1906 to 1907. | Retreat.... | 1,320 ft.... | 1,320 ft. . . | Morse, Klotz. |
| 1907 to Sept. 2, 1911. | Retreat.... | 13,200 ft. *a.* | 3,300 feet.. | Tarr and Martin. |
| 1911 to June. 1, 1912. | Retreat.... | 1,320 ft. *b.*. | 8,745 ft . . | N. J. Ogilvie. |
| June 1 to Aug. 1, 1912. | Retreat.... | 7,425 ft.... | | |

*a.* Estimated, and checked by photographs.

*b.* Accurately measured by Mr. Ogilvie as 14,520 feet of recession from 1907 to June 1, 1912.

PAGE.

137. 2nd line from top—for "47" read *76.*
139. Between "Present Day Glaciers" and "78"—add *65, 66, 72.*
143. Folded map of Hidden Glacier—for "Approximate Location of Front 1908" read *Approximate Location of Front 1905-6.*
143. 18th line from top—for "black glacier" read *Black glacier.*
146. 2nd line from top—following "The moraine terraces," add *evidently to be correlated with the deposits which form the fourth evidence.*
146. 8th line from top—after "evidently" add *the results.*
148. 3rd line in 2nd paragraph—for "72" read *26.*
148. 7th line in 2nd paragraph—for "26" read *74.*
153. 1st line at top—for "destroying " read *deflecting.*
156. In double starred note—for "on" read *in.*
156. 1st line in 3rd paragraph—for "Our" read *Other.*
158. Last line in table—add *Tributary of Anderson glacier; 80 miles northwest; 1912; D. W. Eaton.*
160. After 5th line in table—add *Muir; about 1814; over 1 mile; W. Ogilvie.*
160. 8th line from bottom—for "Before" read *Between.*
176. 7th line from top—For "Reed"read *Reid.*

34883

GUIDE BOOK No. 10.

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# Excursions in Northern British Columbia and Yukon Territory and along the North Pacific Coast.

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CONTENTS.



34883—1½

Coast Range mountains, showing rounded glaciated character.

EXCURSION C 9.

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# PRINCE RUPERT AND SKEENA RIVER

BY

R. G. McCONNELL.

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## CONTENTS.

## VANCOUVER TO PRINCE RUPERT.

The journey along the North Pacific Coast from Vancouver to Prince Rupert is made by ocean steamer. The distance is about 500 miles (804 km.), and the time occupied usually about 36 hours. The journey is continuous, no stops being made; and as much of the coastline is passed in the night, only a brief general description is necessary.

### Physical Features of the Coast.

The route from Vancouver northward along the Pacific Coast follows a long, partially submerged, island-filled depression, bordered continuously on the east by the Coast range and interruptedly on the west by the long mountain ridges of Vancouver and the Queen Charlotte islands.

The Coast range is a deeply dissected granitic ridge usually from 60 to 80 miles (96 to 128 km.) in width. It rises directly from the sea with few intervening flats or plateaus to height of 4,000 to 5,000 feet (1,219 to 1,524 m.), gradually increasing towards the axis of the range to 7,000 or 8,000 feet (2,133 to 2,438 m.) The mountains and mountain ridges are massively built elevations with steep, often craggy, slopes terminating in rounded, dome-shaped, and pyramidal summits. The heights as a rule are very uniform, although a few peaks rise to a considerable elevation above the general level. Deep, ice-worn, steep-sided valleys, often terminating in living glaciers, penetrate the range in all directions, and form one of its most characteristic features. The lower slopes of the mountains, where not too precipitous, are covered everywhere up to a height of 4,000 feet (1,210 m.) with a dense coniferous forest.

A fiord system is well developed all along the Pacific Coast from Vancouver northward. The fiords not only repeatedly penetrate the Coast range for distances which often exceed 100 miles (161 km.) in length, but similar deep, narrow, water-filled depressions, trending in different directions, separate the numerous islands fringing the coast both from each other and from the mainland.

The fiords are all very similar in character. They are steep-sided very regular troughs, usually from one to

two miles in width, sunk 500 to 1,500 feet (152 to 457 m.) below the present sea level. They are occasionally straight, but as a rule follow a winding course, sending off branches at intervals, and often opening out around rocky islands.

Two theories have been advanced to account for the origin of the fiords, one that they have been excavated below sea level by moving ice, the other that the coast has been depressed and that they are sea filled stream valleys smoothed, straightened and probably deepened to some extent by glacial action. The complexity of the system, the presence of midstream islands, and the northerly trend of a not inconsiderable number of the fiords are difficult to explain if the cutting was done entirely by ice.

## Geology.

The Pacific Coast from Vancouver northward for several hundred miles is bordered continuously by a wide belt of granitoid batholithic rocks, the intrusion of which commenced and reached its maximum in upper Jurassic times, but continued also into Cretaceous times. These rocks vary little in general character along the coast for hundreds of miles. They are described in connection with excursions C1, C2 and C8. The ordinary variety outcropping everywhere along the coast is a coarse, greyish granodiorite, usually massive, but frequently distinctly gneissic. Dark basic and light colored acid varieties are not uncommon, but seldom cover large areas. The roof of the long line of batholiths has been largely removed by erosion, but inclusions of the rocks through which they were intruded, ranging in size from small fragments to areas several miles across, are seldom absent in sections across the granitic belt.

Between Vancouver and the northern end of Vancouver island, the western edge of the series of batholiths follows closely the mainland coast, and sedimentary and volcanic rocks, referred mostly to the Triassic, outcrop in the bordering islands. North of Vancouver island, the coast trends more to the north, and the groups of islands fringing it northward nearly to the mouth of the Skeena are all granitic in character. Opposite the mouth of the Skeena, a wide belt of altered sedimentary rocks, mostly quartz mica schists and crystalline limestones, border the

batholithic rocks on the west and are exposed in islands in Chatham sound and in a strip along the mainland.

## Annotated Guide.

### VANCOUVER TO PRINCE RUPERT.

**Gulf of Georgia.** This long irregular arm of the sea, separating the southern part of Vancouver island from the mainland, is followed north-westward from Vancouver to Valdez island, a distance of 150 miles (241 km.). The depression it occupies, usually from 12 to 20 miles (19 to 32 km.) in width, is attributed to crustal warping in Tertiary times along the western border of the Coast Range batholith. The depressed area is only partially submerged, the more elevated portions still rising above the surface as rocky islands.

Texada island, 50 miles (80 km.) northwest of Vancouver, the largest of these uncovered ridges, has a length of 30 miles (48 km.) and is built largely of massive porphyrites, probably of Triassic age, intrusive into a limestone referred on imperfect fossil evidence to the Carboniferous. The coal-bearing Cretaceous strata of Vancouver island formerly extended eastward across the gulf to Texada island, but have been largely removed by erosion, and are now only found in small isolated patches in sheltered basins along the west coast.

Texada island is well mineralized with deposits of the contact metamorphic type, situated usually near small dioritic or granitic stocks intruding the porphyrites and limestones. The ore bodies in the Marble Bay mine on the east coast, consisting mostly of bornite and chalcopyrite in a garnet-epidote-augite gangue, have proved very persistent, and the workings have now reached a depth of 1,170 feet (356 m.) below the land surface and 1,120 feet (341 m.) below sea level. An important range of magnetite lenses, some of large size, occur near the west coast along irregular granite-limestone and porphyrite-limestone contacts.

Glacial deposits made up of two boulder clays separated by a thick band of sands, silts and gravels, interglacial in age, form conspicuous banks in isolated areas on Texada, Savary, and other islands in the gulf, and also occur at intervals along both coasts. The beds in the

different areas are very similar in general character and sequence, and probably represent erosion remnants of a continuous, or nearly continuous sheet, which spread across the gulf and filled the depression it occupies to a height of about 300 feet (91 m.) above the present water level.

**Valdez Island.** The depression between the Coast range and Vancouver island is occupied north of the gulf of Georgia by the Valdez islands. They are separated from Vancouver island by a narrow strait, swept at the Seymour Narrows constriction by strong tidal currents.

The Valdez islands are situated along the contact between the batholithic rocks of the Coast range, and the bordering volcanics and sedimentaries, and like Texeda island are extensively mineralized.

**Queen Charlotte Sound.** North of the Valdez islands the channel between Vancouver island and the mainland gradually opens out into the Queen Charlotte sound, an irregular island-filled body of water extending northwestward to the head of Vancouver island. The numerous rocky islands in the sound are built mostly of massive and fragmental volcanics of Triassic age associated with argillites, quartzites and limestones. An outlier of coal-bearing Cretaceous strata occurs on the Vancouver island side opposite Malcolm island. Granitic batholithic rocks outcrop all along the mainland coast.

**Fitzhugh Sound.** North of Vancouver island, an open stretch of water exposed to the Pacific, about 25 miles (42 km.) in width, is crossed to Fitzhugh sound between Calvert island and the mainland. North of this point nearly to the mouth of the Skeena, a distance of 150 miles (241 km.), the ordinary steamship route follows a succession of narrow, often extremely picturesque, channels separating an almost continuous line of rocky, granitic islands from the mainland. The coast line is indented with numerous bays and deep fiords. Dean canal, one of these fiords, with its continuation, the valley of Salmon river, cuts completely across the Coast range.

**Princess Royal Island.** This is the largest island on the route north of Vancouver island. It is mountainous

throughout and is practically a portion of the Coast range, but is separated from it by a continuous deep channel. It is built mostly of greyish, gneissoid granites or granodiorites. Large gold bearing quartz veins occur in places near its west coast.

**Grenville Channel.** This channel separates Pitt island from the mainland. It is a typical fiord, and is remarkable for the straight course it follows. It has been excavated along a narrow band of schists, widening to the north, included in the batholithic rocks. Pitt island, like Princess Royal island, is monotonously rough and mountainous along its whole length of 50 miles (80 km.) Some of the triangular granite peaks reach elevations of 5,000 feet (1,524 m.)

**Chatham Sound.** From Grenville channel the southern part of Chatham sound is crossed to Prince Rupert, situated on Kaien island north of the mouth of the Skeena. A large inclusion or bay of sedimentary rocks lies in the batholith at this point, and exposures of schists and altered limestones occur in most of the low islands scattered along the sound.

## GENERAL PHYSICAL FEATURES OF THE SKEENA RIVER DISTRICT.

The region traversed in the excursion from Prince Rupert to Telkwa, now made accessible by the construction of the Grand Trunk Pacific Railway, was practically unknown until recent years except to the furtrader, prospector and an occasional explorer, and even at present surveys are practically limited to the main waterways, and only the general geological features have been ascertained. The district includes the Coast range and a portion of the mountainous Interior region bordering it on the east, and bold relief is the dominant feature everywhere.

The Coast range, where crossed, has a width of about 60 miles (96 km) and, with the exception of some included schists, is everywhere carved out of coarse granitoid rocks. The mountains in the immediate vicinity of the Skeena valley are not high, seldom exceeding 5,000 feet (1524 m). They are as a rule densely forested below, and steep and

craggy above, but have been toned down by the moving ice of the Glacial period and rendered somewhat monotonous. Higher, partially snow-covered, and more impressive peaks are occasionally seen up tributary valleys. Small glaciers of the Alpine type occur at a few points, but do not descend to low levels.

The eastern boundary of the Coast range is not always easy to define, as it often merges insensibly into the high plateaus and mountains of the Interior. On the Skeena the main range is bordered on the east by a wide depression occupied north of the Skeena by the Kitsumgallum river. This great trench, 4 to 5 miles (6.4 to 8 km) wide in places, extends northward to the Nass and southward across the Coast range, reaching the sea at the head of Kitimat arm. It evidently represents an old, partially abandoned, valley of erosion possibly robbed by the Skeena.

East of the Kitsumgallum valley a second wide range of high nameless mountains, mostly built of schist and granite, is crossed. These connect to the south with the Coast range and may be considered a spur from it. After passing them the dry interior district is reached, and a change in the topography is immediately noted. The valleys of the Skeena and its tributaries become much wider, are frequently terraced, and the relief is expressed in long even ridges, or in isolated groups of high peaks mostly built of upturned Jurassic and Cretaceous strata surrounding granite cores. Among the prominent groups are the Rochers Déboulés at the confluence of the Skeena and Bulkley rivers, some peaks of which reach elevations of over 8,000 feet (2,438 m), and judging from their rugged angular character evidently exceeded the limits of glaciation, and the lofty Hudson Bay mountains bordering the Bulkley on the southwest.

The Skeena river, which is followed by the railway from its mouth eastward through the Coast range to its junction with the Bulkley, heads in some of its branches with the Fraser, and like it drains a large portion of the rough elevated country lying between the Coast range and the Rocky mountains. It is a wide, swift flowing stream, repeatedly dividing around low alluvial islands in its passage through the Coast range. In its upper reaches it becomes more confined and its course is interrupted by numerous short boulder-strewn rapids and by occasional canyons. It is ascended by river steamers to Hazelton at

the mouth of the Bulkley, a distance of 154 miles (247.8km), but its navigation, except near the mouth, is difficult and dangerous.

The valley of the Skeena, where it cuts the Coast range, is a deep, steep-sided trough, precisely similar to the fiord-like depressions filled with salt water so prevalent along the coast. It has however, been gradually silted up by the river down to about Mile post 40, and is bottomed with alluvial flats and islands. Above the mouth of the Kitsumgallum its character changes. The valley above this, at the end of the Glacial period was floored for some distance by estuarine, and farther up by glacial deposits, and in place of depositing its load the river is scouring out, and along most of its course is sunk in a secondary valley.

The secondary valley is mostly in drift, but along considerable stretches it cuts through these loose deposits down into the bed rock beneath, and contracts into a canyon. The rock walled portions are due, in part at least, to deviations of the stream from the lowest portions of its pre-glacial channel. Some of them may owe their origin to small post-glacial uplifts.

The Skeena valley, east of the semi-crystalline rocks which border the Coast Range batholith on that side, enters a more easily eroded region where it gradually expands in width, and the bordering slopes become much less regular.

The Bulkley river, which is followed after leaving the Skeena, is a wild unnavigable stream plunging over rapids or crowding through canyons along its whole course. The enclosing valley is very large, its width ranging from four (6.4 km.) to nearly ten miles (16 km.). It is bordered on the southwest, from the Skeena to Moricetown, by the high rugged Rochers Déboulés mountains, and from Moricetown to the Telkwa by the almost equally rough Hudson Bay mountains. On the northeast the bounding elevations are low and more even, seldom breaking into prominent peaks.

The valley is heavily drift covered, and a cross section usually shows a central terraced portion, bordered by uneven slopes, leading up to the bounding ridges and mountains. The river is sunk in a secondary, and for long reaches, rock-walled valley from Hazelton to Telkwa.

The grade of the Skeena from Essington, where the current practically ceases, to Hazelton, a distance of 154

miles (247.8 km.), averages 4.2 feet per mile (1.8 m. per km.), and that of the Bulkley from Hazelton to Telkwa, a distance of 58 miles (93.3 km.), 17.1 feet per mile (5.2 m. per km.). The elevation at Telkwa is 1,650 feet (502.8 m.) above sea level.

## NATURAL RESOURCES.

The principal natural resources of the district consist, on the coast, of fisheries and the product of the forest, and in the interior of agriculture and mining.

The Skeena is a noted salmon river, and the fishing industry has been established on a firm basis for some years, and is still growing. The product of the numerous salmon canning establishments, located on islands off the mouth of the Skeena and along the mainland, is very large, in favourable seasons exceeding 200,000 cases. Other fishes of commercial importance are the cod, herring, oolachan, and farther away, near the Queen Charlotte islands, the halibut.

The Coast district is forested, practically everywhere, up to a height of about 4,000 feet (1,219 m.) above sea level. The principal forest trees along the lower part of the Skeena are the hemlock (*Tsuga Mertensiana*), the stately Sitka spruce (*Picea Sitchensis*), specimens of which frequently attain diameters of from 6 to 8 feet (1.8 to 2.4 m.), and the white fir (*Abies grandis*). The cottonwood (*Populus trichocarpa*) is well represented along the lower flats. Less common trees are the valuable yellow cedar (*Chamaecyparis nootkatensis*), and the red cedar (*Thuya gigantea*).

The area of land available for agriculture is very limited near the coast, but the country east of the Coast range, although generally rough and mountainous, contains a number of large areas suitable for this and kindred purposes. Among the most important of these are, the wide longitudinal depressions which follow the Kitsumgallum and Kitwancool rivers from the Skeena north to the Nass, the benches along the upper Skeena, and the great terraced valley of the Bulkley. Production as yet is small because settlement has barely commenced. It includes small fruits and apples in the valley of the Kitsumgallum, and roots and hardy cereals farther inland.

The mining industry is also only in its initial and experimental stages, but promises a rapid development. The mineral resources of the district include, bituminous coal in considerable areas in the valleys of the Telkwa and Bulkley rivers and other places, and lignitic coal on Driftwood creek. Numerous discoveries of metalliferous veins, some of large size, have also been made. These usually occur in the vicinity of intrusive masses which cut the rocks of the Hazelton formation, and are especially abundant in the mountains bordering the Bulkley on the east, south of Hazelton, and in the Hudson Bay, Babine, and Rochers Déboulés mountains. Silver-bearing galena and chalcopyrite are the principal valuable minerals present. The associated minerals include pyrite, arsenopyrite, zinc blende, stibnite, tennantite, and tetrahedrite.

Development work is in progress on a number of the properties, and on a few, considerable bodies of good ore have already been opened up.

## GEOLOGY.

The formations traversed along the route of the excursion embrace the granitoid rocks and included schists of the Coast Range batholith, bordered on the west by altered sedimentaries, and on the east by a complex of partially altered volcanics. The latter are overlaid and succeeded eastward by a wide belt of middle Mesozoic, mostly tufaceous, rocks, intruded at numerous points by granite stocks.

A marked feature of the section is the preponderance along it of rocks of igneous origin, both intrusives and extrusives being widely represented.

The rocks have been subdivided into the following groups:—

### SEDIMENTARIES AND VOLCANICS.

| | |
|---|---|
| Lower Cretaceous | Skeena formation. |
| Jurassic, possibly including some Lower Cretaceous | Hazelton formation. |
| Triassic? | Kitsalas formation. |
| Upper Paleozoic? | Prince Rupert formation. |

INTRUSIVES.

| | |
|---|---|
| Jurassic to Lower Cretaceous.... | Coast Range batholithic rocks. |
| Post-Lower Cretaceous.......... | Granodiorite stocks, east of Coast range. |

**Skeena Formation.** The rocks of this formation occupy isolated basins folded in with those of the Hazelton formation, and resting apparently conformably or nearly so on them. The exact relationship has not been worked out. The varieties commonly present are felspathic sandstones, conglomerates, hardened clays, shales usually more or less carbonaceous, and occasional seams of coal. The beds are less indurated than those of the underlying Hazelton formation, are seldom fractured, and usually undulate in open folds.

The shales are plant bearing in places. A small collection made by W. W. Leach and reported on by Dr. Penhallow contained the following species:—

*Sequoia Rigida*, Heer.
*Thuya Cretacea*, (Heer) Newberry.
*Thyrsopteris sp.*

These species indicate an age equivalent to the Kootenay or lowest Cretaceous.

**Hazelton Group**. The beds of this formation overlie the semi-crystalline Kitsalas formation at Mile Post 123 on the railway, and they are the principal rocks exposed along the Skeena and the Bulkley rivers up to Telkwa, the terminal point of the excursion.

The Hazelton rocks are mostly tufaceous in origin, but, unlike those of the Kitsalas, they are well bedded and banded, and are seldom much altered except in the immediate vicinity of intrusive masses. The predominating variety is a heavily banded, bluish grey, rather even grained rock, made up of minute rock fragments usually andesitic in character, with some broken feldspar crystals and occasional angular grains of quartz. Dark argillaceous beds and bands alternate with the tuffs and tufaceous sandstones. These are usually more or less carbonaceous, and in places, carry thin streaks of coal. Conglomerates

made up of well rolled greenstone, occasionally granite and slate, pebbles in a tufaceous cement also occur, but are not common.

The Hazelton tufaceous rocks, while probably mostly deposited in shallow water, were occasionally built up on land. North of Porphyry creek, a heavy band in the series is made up of a confused mass of grey tuffs, which grade into fine and coarse breccias holding numerous rounded andesitic bombs often two feet (.6 m.) or more in diameter. In portions of the region, especially from Moricetown southward along the Hudson Bay mountains, the fragmental volcanics are interbanded with rocks, mostly green, occasionally red, andesites.

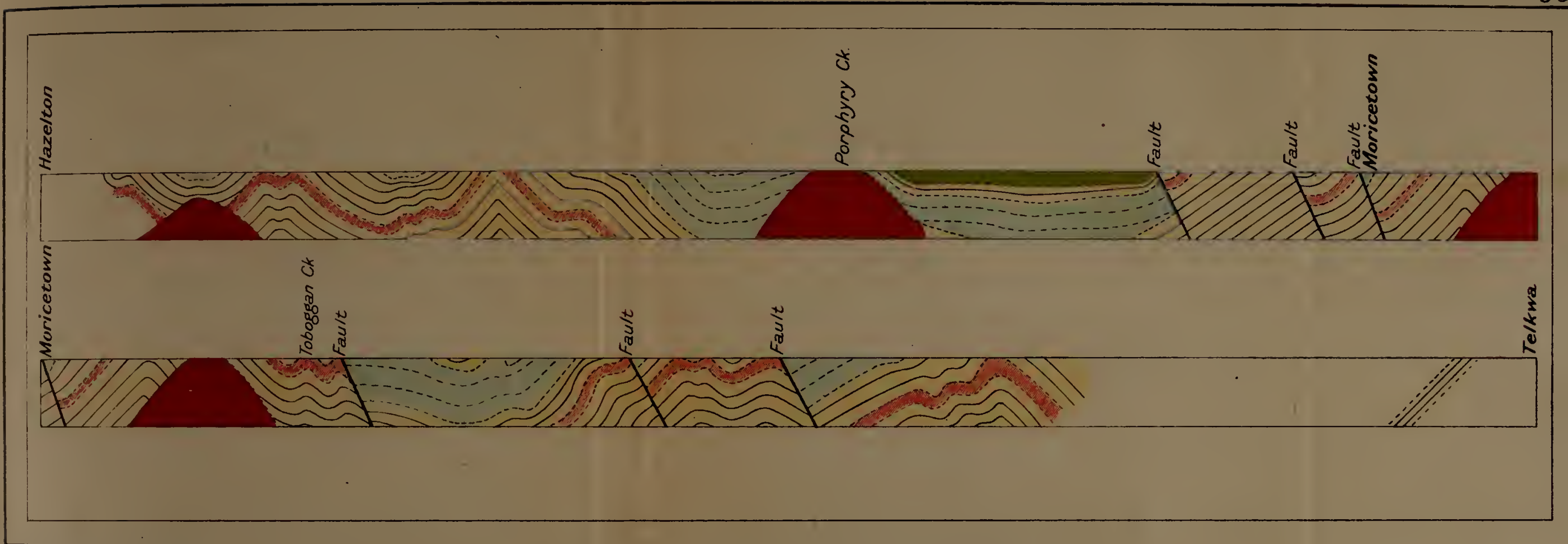
No complete section across the basin occupied by the Hazelton rocks has so far been made. The thickness is consequently unknown, but it is estimated to exceed 4,000 feet (1,219 m.). The beds and associated andesite sheets are occasionally flat, or nearly so, for short distances, but are usually compressed into open, more rarely close, folds, and in places are strongly contorted. Faults are numerous, and in most of the sections the rocks are fissured and traversed by small calcspar veinlets.

Large veins, important for their metalliferous contents, chiefly silver-bearing galena, blende and chalcopyrite, occur in the formation, Several of these are now being explored.

The range in age of the Hazelton formation has not been definitely established. Fossil plants occur in a number of the shaly bands, and a few shells, usually imperfectly preserved, have been collected at several points. These indicate an age ranging from Jurassic up to Lower Cretaceous.

Collections of fossils, made by W. W. Leach from the upper part of the formation and reported on by Lawrence Lambe, include the following specimens.

*Belemnites skidegatensis*, Whiteaves.
*Nerinea maudensis*, Whiteaves.
*Pleuromya papyracea*, var. Carlottensis, Whiteaves.
*Astarte carlottensis*, Whiteaves.
*Trigonia dawsoni*, Whiteaves.
*Inoceramus concentricus*, Parkinson.
*Pecten (entolium) lenticularis*, Whiteaves.
*Pecten carlottensis*, Whiteaves.
*Thracia semiplanata*, Whiteaves.



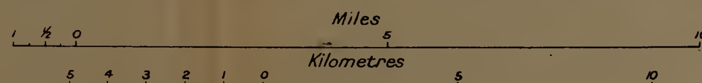

Geological Survey, Canada.

**Lower Cretaceous** — Skeena formation (coal-bearing)

**Jurassic** possibly passing up into **Lower Cretaceous** (Hazelton formation) — Tuffs and tufaceous sandstones; Andesitic flows and breccias; Sandstones, grey, black, and carbonaceous shales

**post-Lower Cretaceous** — Intrusives chiefly granodiorite

General section along **Bulkley River** from **Hazelton** to **Telkwa** — by W. W. Leach



**Kitsalas Formation**. The Coast Range batholith is bordered on the east along the Skeena river by a wide belt of volcanics associated with some sedimentary rocks, which have been grouped together as the Kitsalas formation. They are repeatedly intruded by granitic dykes and stocks, and in places, are somewhat schistose, but the alteration is nowhere so complete as in the rocks flanking the batholith on the west. Ordinarily they are greenish to purplish massive rocks spotted with large, rounded, and irregular areas of epidote, and lined along fracture planes with the same mineral.

The formation is made up near the batholith of porphyrites, tuffs, and coarse fragmentals, welded closely together, and seldom showing traces of bedding or banding. Farther to the east, the volcanics alternate with dark and light grey, micaceous sedimentaries. The rocks are everywhere highly altered, in places to such an extent as to obscure their origin, but are seldom conspicuously schistose, except along fracture zones.

The age of the old volcanic complex, represented by the Kitsalas formation, is uncertain. It is older than the Coast Range batholith and is placed tentatively in the Triassic.

**Prince Rupert Formation.** The Coast range in the vicinity of Prince Rupert is flanked on the west by a wide band of metamorphic rocks, for which the name Prince Rupert formation is proposed. These rocks, originally, were mostly argillaceous, siliceous and calcareous sediments, but have been intensely altered and converted into mica, quartz mica, and hornblende schists, and crystalline limestones. Occasional areas of diorite or gabbro, intruded prior to the folding of the region, are now represented by coarse hornblende schists. West of Prince Rupert, in the western part of Digby island, green chloritic and hornblende schists, derived from fragmental and massive volcanic rocks, occur interbanded with the dark grey, sedimentary schists.

In the section exposed along the railway from Prince Rupert eastward to the western edge of the Coast Range batholith, the limestones and crushed volcanics are absent, and the principal variety is a moderately coarse, well crystallized, quartz mica schist, made up mostly of biotite and angular quartz grains, arranged in alternating lines

and narrow lenses Some carbonaceous dust is also usually present, and pyrite and garnet are common secondary minerals. In places, there is an alternation of dark grey and light grey bands, the former representing the more micaceous, and the latter, the more siliceous varieties. The degree of crystallization also varies, the rocks ranging from phyllites to fine grained gneisses.

Approaching the granitic batholith there is no notable increase in the crystallization, or in the quantity of secondary minerals present, but aplitic dykes become more common and in the last sections seen, the rocks frequently have a striped appearance due to the intrusion of small acid dykes along the bedding planes, and to the silicification of layers of the schists.

The Prince Rupert schists east of Prince Rupert, have a uniform easterly dip of 30 to 70 degrees towards the granitic batholith, and a N. N. W. strike approximately parallel to the western edge of the batholith. West of Prince Rupert, on Digby island, the structure is more complicated and has not been worked out in detail. The tilting and folding of the beds and the crystallization of the sediments in part, at least, as first explained by Spencer [**6**. p. 19] and confirmed by subsequent observers, probably preceded the granitic invasion.

The age of the schists, while not definitely known, is probably upper Carboniferous, some confirmatory fossil evidence having been obtained by F. E. and C. W. Wright [**8**] in corresponding rocks farther to the north in southeastern Alaska.

**Coast Range Batholithic Rocks.** The belt of granitoid batholithic rocks which follows the mainland coast of British Columbia and Alaska continuously for nearly 850 miles (1,368 km.) from Fraser river north to latitude 61° N, has a width where crossed by the Skeena river, of 58 miles (93 km.) This long granitic mass, formerly considered to be the product of a single linear invasion, is really made up of a number of batholiths separated in age by considerable time intervals. The intrusions commenced in the Jurassic, and on the evidence of bordering satellitic stocks, probably continued into Lower Cretaceous.

The rocks represented in the line of batholiths range from acid granites to gabbros. The prevailing variety

is a grey medium grained, usually massive, but occasionally coarse, gneissoid rock, intermediate in character between the diorites and granites, and classed generally as a granodiorite. Inclusions of fragments and even large areas of the intruded rocks are common in them.

Along the Skeena river, the Coast Range section is made up of wide bands of light and dark grey granodiorites, alternating with bands of dark basic schists, the largest six miles (9.6 km.) across. The granodiorites in this section show a more or less pronounced gneissic structure everywhere. Along their western margin the schistosity conforms generally in dip and strike with that of the bordering easterly dipping altered sedimentaries. Farther on, the direction and angle of dip varies from point to point, and in a few places the lines of schistosity are sharply plicated. The gneissic structure is considered to have been assumed during the cooling of the granitic magma, and not to be a product of subsequent dynamic deformation.

In the Skeena section there is no clear evidence of more than one period of intrusion, and the granodiorites, except for slight differences in coloration and an occasional banded arrangement due to a concentration of the dark minerals, have a very uniform character across the range. They are medium to coarse grained rocks, occasionally showing a porphyritic texture, made up of a plagioclase feldspar, usually andesine, orthoclase, microcline, quartz, and either or both biotite and hornblende. Apatite, titanite, and magnetite are common accessories, and epidote and, less frequently, pyrite and garnet are conspicuous secondary minerals. The following table by F. E. and C. W. Wright [8 p. 64] shows the mineral composition of the average batholithic rocks in the Coast range in southeastern Alaska.

| | |
|---|---|
| Quartz | 19·4 |
| Orthoclase | 6·6 |
| Andesine ($Ab_{.56}$ $An_{.44}$) | 47·4 |
| Hornblende | 7·6 |
| Biotite | 11·6 |
| Apatite | ·6 |
| Magnetite | ·9 |
| Pyrite | ·1 |
| Carried forward | 94·2 |

| | |
|---|---|
| Brought forward | 94·2 |
| Titanite | 1·3 |
| Epidote | 3·5 |
| Chlorite | ·1 |
| Calcite | ·1 |
| Kaolin and Muscovite | ·8 |
| | 100·0 |

This rock is more closely related to the diorites than the granites, and might appropriately be called a quartz diorite or tonalite.

The basic bands included in the granodiorites are made up mostly of dark micaceous and hornblendic schists and fine grained gneisses. They are considered to represent unabsorbed, in places partially absorbed, portions of the intruded rocks, but have been so intensely altered and completely recrystallized that all traces of their original character have disappeared. They often alternate with, or are cut across by bands, of granodiorite, and in some instances have a brecciated appearance due to the number of granitic, aplitic, and pegmatitic dykes crossing them in all directions. Near the basic areas, the granodiorites are usually strongly and regularly banded, the dark bands closely resembling varieties of the included schists.

The basic schists dip at various angles, but in one area are nearly horizontal. The direction of schistosity conforms as a rule with that of the enclosing gneissic rocks.

Aplitic and pegmatitic dykes occur everywhere cutting both the granodiorities and the included schists, but are especially abundant along the western margin of the range. The pegmatite dykes are often of large size, and, as a rule, are very coarsely crystalline. The ordinary constituents are white orthoclase, light pink microcline, quartz, and dark and white mica. Secondary garnets are occasionally present. It is noteworthy that the acid dykes, although belonging to the closing stages of the intrusion, are nowhere schistose themselves. In the western portion of the range they usually cut the schistose granodiorites almost at right angles.

Small basic dykes, younger than the aplites and pegmatites, occur in the range, but are nowhere plentiful in the Skeena section. The common varities are diabases and hornblende lamprophyres.

**Intrusives east of the Coast Range**. The volcanic and sedimentary rocks bordering the Coast range batholith on the east up to and including the Skeena formation are repeatedly intruded by stocks, some of large size, very similar in mineralogical composition to the batholithic rocks, and classed generally as granodiorites. The ordinary variety is a greyish medium grained, massive rock usually granular in texture, but often becoming porphyritic. Dark diorite and light coloured acid porphyritic phases are not uncommon.

These stocks probably belong to the closing stages of the prolonged period of vulcanism in which the long Coast range group of batholiths was intruded. They cut rocks of Lower Cretaceous age, but are not known to intrude the overlying Tertiary rocks.

**Glacial and post-Glacial Deposits**. The district at the height of the Glacial period was covered everywhere up to an elevation of about 6,000 feet (1,828 m.) by a great confluent ice sheet. The general movement of the ice east of the Coast range was southerly, but a hugh stream, as shown by numerous strong groovings along the mountain slopes, poured westward to the sea down the valley of the Skeena.

At the close of the Glacial period, the district was depressed, and Skeena valley was occupied by a long arm of the sea which extended through the Coast range into the Interior region. Since then there has been a gradual elevation of at least 500 feet (152.4 m.), the sea has retreated and the mouth of the river has progressed steadily down the valley.

The deposits, illustrative of these changing conditions, consist of boulder clays, estuarine clays, sands and gravels, and fluviatile sands and gravels.

The boulder clays in the lower portion of the valley have been largely destroyed or buried up to Mile post 160, a short distance below the mouth of the Kitsequecla river. Above this point, the valleys of both the Skeena and Bulkley are covered with a nearly continuous irregular sheet thinning out on the ridges and deepening in the depressions. In places, the sheet attains a thickness of over 200 feet (61 m.). The common variety is dark in colour, exceedingly plastic, and thickly packed with scratched boulders and pebbles.

The boulder clays are often overlaid and underlaid, and more rarely interbanded with stratified clays, sands and gravels.

The estuarine deposits, mostly dark, plastic, stratified clays with associated sands and gravels, have been largely destroyed along the valley of the Skeena, and occur only in isolated patches. No fossils were found in them, but similar beds occupying a like position on Bear river at the head of Portland canal contain numerous shells of species still existing in the nearby ocean.

The estuarine deposits, and the boulder clays along the central portion of the valley, are overlaid by river sands and gravels. The older deposits were cut through as the land rose and the river deepened its channel, and now occur on benches at various elevations above the water level up to at least 300 feet (91.4 m.).

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## ANNOTATED GUIDE.

### PRINCE RUPERT TO TELKWA.

The route of the excursion lies over a completed or nearly completed section of the Grand Trunk Pacific railway from Prince Rupert to Telkwa, a distance of 235·5 miles (378·9 km.). The Skeena river and its tributary, the Bulkley, is followed throughout.


Geological Survey, Canada.

Route map between **Prince Rupert** and **Telkwa**

Miles: 5 0 10 20 30

Kilometres: 5 0 10 20 30 40 50

**Prince Rupert.**—Prince Rupert is at present a straggling town of about 5,000 inhabitants, but has hopes of some day becoming a great world port. It possesses a magnificent harbour, and is the Pacific Coast terminus of the Grand Trunk Pacific railroad, the shortest route to the Orient. It is at present the centre of large and thriving fishing and lumbering industries, and its northerly situation places it in a position to control the trade both of the Yukon and the great interior region of northern British Columbia. This trade is comparatively small at present, but must rapidly expand with the settlement of the country and the development of the mining industry.

Leaving Prince Rupert, the railroad partly rounds Kaien island, and at Mile 7, crosses to the mainland, where it follows up the bold northern shore of the island-filled estuary of the Skeena. On the left are the low Porpoise islands, and farther on, Smith island, a wooded mountain block rising steeply from the sea, is passed.

The rocks along this part of the route consist of the greyish, easterly dipping, quartz mica, and hornblende schists of the Prince Rupert formation, intruded by a few granitic dykes and stocks. They are traversed by numerous small quartz and quartz-calcite veins, and, in places, are spotted with small garnets. These rocks are well exposed in the vicinity of Prince Rupert, and in long cuts all along the railway.

**Mile 16.**—The last exposure of the Prince Rupert schists occurs at this point. They are here in close proximity to the Coast Range batholith, and in places have a striped appearance, due to the intrusion of small aplitic dykes and to the partial silicification of thin bands parallel to the bedding planes.

The actual contact between the schists and batholithic rocks is concealed along the railway.

**Mile 16·7.—Sockeye.**—Immediately west of Sockeye station coarse gneissic granodiorites occur, and these rocks, the main component of the batholith, are exposed at intervals for many miles eastward.

**Mile 17·5.**—Good sections of the gneissoid granodiorites occur at this point. They are cut by numerous light coloured aplitic dykes and by large, coarse textured pegmatite dykes often with an aplitic border. The dykes are not all contemporaneous, as they are frequently found cutting each other, and are occasionally faulted.

**Mile 36 to 39.**—The granodiorites in this stretch are mostly replaced by dark micaceous and hornblendic schists, probably highly altered inclusions, cut by numerous dykes. East of the basic schists, the granodiorites are banded for some distance, and contain frequent dark patches.

The Skeena River valley opposite Sockeye and eastward to Port Essington, Mile 24, is wide and filled with brackish water. Above this point, the valley narrows and a gradual change from estuarine to river conditions is noted. The sediment brought down by the river is mostly deposited in this stretch of slackening current, and long sand bars are slowly emerging above the surface. Farther up these are replaced by low wooded alluvial islands. The effect of the tides is felt up to Mile 60.

The bordering mountains, usually from 3,000 to 4,000 feet (914 to 1,219 m.) in height, are wooded nearly to their summits, and crowd closely down to the water's edge. There are few intervening flats, except at the mouths of tributary streams.

**Mile 44·9.**—The Kwinitsa river, a small stream, enters the Skeena at this point, and the junction is marked by a large flat built of alluvial sands, silts, gravels and clays. One of the gravel beds a few feet below the surface, is saturated with brine. The brine is considered to be imprisoned sea water, somewhat concentrated, left behind during the retreat of the sea in post-Glacial times. The Skeena water opposite this point, although affected by the tides, is now quite fresh.

**Mile 46 to 48.**—A second band of dark basic schists is crossed at this point, and the bordering granodiorites are banded light and dark grey for some distance to the east.

**Mile 48 to 68.**—This section may be considered the heart of the Coast range. The mountains, while not high, are steep, boldly sculptured, and in places singularly impressive. Opposite the the Exstew river a number of small glaciers are seen south of the valley, clinging to the upper levels of the range. They occupy a wide cirque-like depression probably excavated by themselves. The glaciers here as elsewhere in the range are slowly dwindling.

The trough shaped valley of the Skeena is seldom less than a mile in width, and the river, split into a multitude

of channels, swings from bank to bank washing alternately the slopes on either side.

The valley bottoms are flat and built of alluvium, and there is a marked absence all across the range of boulder clay and other deposits of the Glacial age. These have either been destroyed or buried beneath recent river accumulations.

**Mile 68 to 74.**—A wide band of crystalline schists, the widest in the range, occurs at this point. The dark micaceous schists occur in bands, occasionally broken and brecciated, and in lenses alternating with striped and banded gneisses. Aplite and pegmatitic dykes, cutting all the varieties, occur in places, but are not so numerous as in the western part of the range. The schistosity here is often flat or in easy folds.

**Mile 83.**—The eastern border of the main Coast Range batholith is crossed at this point. Its junction with the bordering rocks of the Kitsalas formation is concealed along the railway.

**Mile 83 to 91.**—Almost continuous exposures of the rocks of the Kitsalas formation are displayed in the numerous cuts along this stretch. The rocks are largely of volcanic origin and include porphyrites, andesites, and altered tuffs and breccias. They show considerable fracturing, but are only rarely crushed into schists. A feature of the formation is the extensive development of epidote in rounded and irregular kernels and along fracture planes. Granitic dykes are numerous.

**Mile 91.**—The Coast Range mountains gradually decrease in height from Mile 86 eastward, and at Mile 91 a wide valley occupied north of the Skeena by the Kitsumgallum river is reached. This great depression, four miles in width where crossed by the Skeena, traverses the country in a north and south direction, completely piercing the Coast range, and is evidently of great age, long antedating the initiation of the present drainage system. Its origin and history have not been worked out. North of the Skeena, the valley is floored with heavy deposits of sand, loose gravels and clays, post-Glacial in age and partly marine in origin.

A change in the character of the Skeena River valley is noticed after passing the mouth of the Kitsumgallum. Below this point steady deposition has been going on since the retreat of the sea, and the valley bottom is a maze of

low alluvial flats and islands. The few terraces present have been mostly built up by detritus brought down by tributary streams. Above the Kitsumgallum, the river is engaged in scouring out its old channel partially filled up by over sedimentation during the closing stages of the Glacial period.

**Mile 95·2 to 104.**—East of the Kitsumgallum river the Kitsalas volcanics are replaced for some miles by granodiorites, often porphyritic in texture. These rocks are precisely similar in mineral composition to those in the main Coast Range batholith, and may be a spur from it. They are not schistose, but are strongly jointed and, in places, have a columnar appearance due to the intersection of two sets of jointage planes. They include numerous fragments of the neighboring dark rocks, and are cut by acid dykes and by a later group of coarse basaltic dykes.

**Mile 104. Kitsalas Canyon.**—The Skeena river here forces its way through the narrow rock-walled Kitsalas canyon, one of the most picturesque points in its course.

The canyon is about a mile in length, and in places, scarcely 100 feet (30.4 m.) in width, and is sunk through the greenish and greenish-grey volcanics of the Kitsalas formation, the junction of these with the granites occurring near its foot.

The origin of the canyon is plain. The valley here at the close of the Glacial period, when the Coast region was depressed, was filled with estuarine clays, sands and gravels to a height of 170 feet (51.8 m.) above the present water level. On the retreat of the sea the river commenced cutting down through these, and the canyon marks a reach where the new channel deviated from the old one, and crossed a buried spur from the bordering mountains.

In passing Kitsalas canyon the roughness of the ground necessitated the construction of four tunnels on the railway, one through a clay ridge.

**Mile 105 to 112.**—Occasional cuts along the railway expose the rocks of the Kitsalas formation. They are more schistose than farther west and in places resemble the Prince Rupert altered sedimentaries.

**Mile 113.**—A long cut across a low terrace at this point exposes estuarine clays and sands overlaid by river wash.

**Mile 113·5 to 122·9.**—A second large stock of massive grey granodiorite, intruded through the rocks of the Kitsalas formation, is crossed in this reach.

The mountains bordering the valley from Kitsalas canyon eastward to this point and for some distance beyond, are considered to be a northerly spur from the Coast range. High snowy peaks and steep serrated glacier-laden ridges are seen south of the valley up gashes cut by tributary streams.

**Mile 122·9.**—The semi-crystalline volcanics and associated sedimentaries of the Kitsalas formation reappear at this point east of the granodiorite stock, but are soon overlaid by the banded tuffs of the Hazelton formation.

**Mile 123·45.**—The first section of the rocks of the Hazelton formation occur at this point. They consist of dark tuffs, alternating with black, fine-grained carbonaceous bands, also tufaceous in character, and sheets of green andesite. The rocks are folded, and are often broken and faulted, but are much less altered than those of the underlying Kitsalas formation.

Similar banded rocks, varying somewhat in texture and colour and occasionally including some conglomerates, are exposed at intervals eastward to Skeena Crossing. The undulate as a rule in easy folds, but in places are steeply tilted, violently flexed and broken. They are cut by a number of diorite porphyrite dykes and small stocks of granodiorite.

**Mile 131.**—The Skeena passes through a short canyon at this point walled with massive bands of grey tuffs and dark carbonaceous shale. The valley is wide, with a terraced central portion bordered by rocky ridges rising farther back into mountains.

**Mile 139·5.**—East of the river is Minskinish, a well built Indian village, and behind it, rises a picturesque group of high peaks known as the Seven Sisters, built mostly of the upturned rocks of the Hazelton formation intruded by a granitic stock. These mountains are placed in the Interior region, although they are not separated from the Coast Range mountains by any marked depression.

**Mile 143·5.**—Tufaceous beds of the Hazelton formation pass into conglomerates made up of well rolled pebbles of greenstone with some granite and slate in a tufaceous matrix.

**Mile 145·4.**—A section exposed at this point shows a heavy conglomerate band associated with tufaceous sandstones.

**Mile 147·3.**—Immediately beyond Ksi-den creek the railway enters a tunnel piercing a narrow gravel plateau. A strong riffle occurs here in the Skeena river, above which the valley opens out into a wide irregular terraced plain.

**Mile 149·4.**—Sections at this point show soft, light colored, tufaceous sandstones interbedded with dark shales.

**Mile 152·2.**—The Kit-wan-cool river, which is crossed at this point, occupies, like the Kitsumgallum, a wide north and south depression extending from the Skeena north to the Nass.

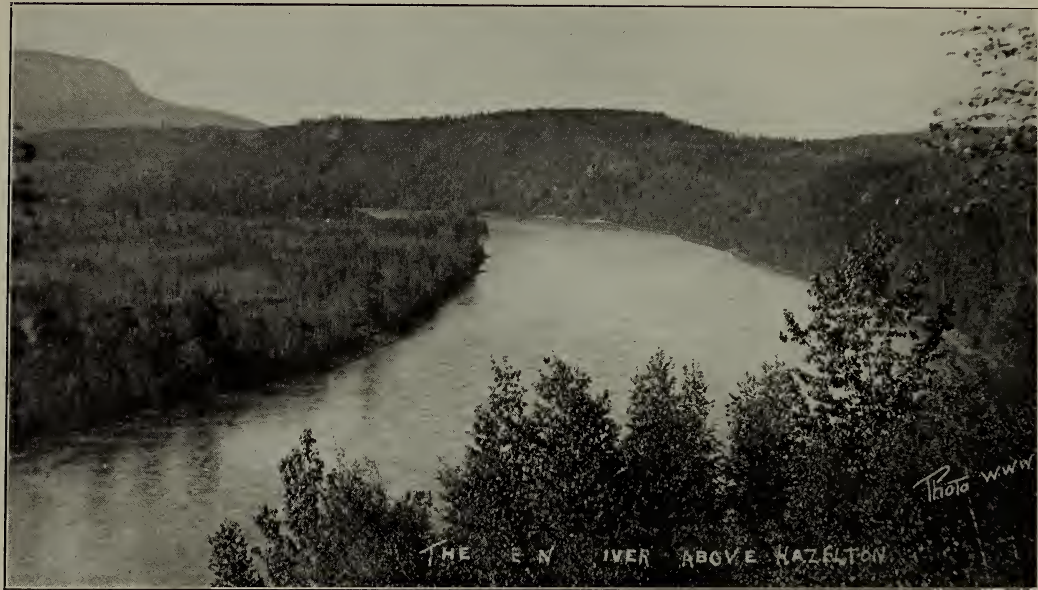
**Mile 156·1.**—The Hazelton beds are here intruded by large altered and fissured diorite porphyrite dykes.

**Mile 161·05.**—Sections of dark plastic boulder clay are here seen for the first time in ascending the valley.

**Mile 163·4.**—The Kitseguecla river, deeply trenched in a long canyon, enters the Skeena from the south. East of it is the Rochers Déboulés range, a long mountain mass breaking in places into high pinnacled peaks and sharp crested ridges.

**Mile 164·2.—Skeena Crossing.**—The railway, which has hitherto followed the left bank of the Skeena, crosses to the right. The river here and for some distance above and below occupies a deep gorge sunk through the drift into the underlying rocks, and a long bridge has been thrown across this at an elevation of 140 feet (42·6 m.) above the water level.

The rocks of the Hazelton group, consisting here of alternating bands and beds of grey, tufaceous sandstones and dark, usually carbonaceous, shales, cut by occasional diorite porphyrite dykes, are well displayed in the walls of the gorge. They have yielded unequally to compression, and sharp bends often accompanied by faulting alternate with long easy folds.




Terraced Skeena valley above Hazelton.

East of Skeena Crossing the railway follows a wide roughly terraced slope, which intervenes between the river and the bordering Rochers Déboulés mountains. The older rocks are mantled everywhere and in places deeply buried beneath, a thick covering of glacial drift.

**Mile 175.**—A small granitic stock more basic than usual, intrusive into the Hazleton beds, crosses the valley.

**Mile 176.**—Seely gulch a deep V-shaped gorge, sunk through boulder clay, joins the Skeena from the south.

**Mile 177.—Hazelton.**—The railway leaves the Skeena at this point and turns to the right up the Bulkley a tributary stream. Both rivers near their junction, have cut deep, terraced, secondary valleys through the drift, Looking northward from the railway level 320 feet (100 m.) above the river, the great mountain-bordered valley of the Skeena is seen stretching far into the distance. Hazelton, an old furtrading post of the Hudson's Bay Company and at present the principal trading centre of the district, is situated in the foreground at the confluence of the two rivers.

**Mile 180·5.**—New Hazelton is situated in a wide flat separated from the river by a rocky ridge, and a road leads from it to old Hazelton, across the Bulkley, which, is here enclosed in a rocky gorge. A good view of the Rochers Déboulés mountains on the southwest is obtained from this point.

Rochers Déboulés mountains, from the junction of the Skeena and Bulkley rivers.

**Mile 183·5.**—The railway, which, since leaving Mile 178, has followed a terraced flat south of the river approaches and joins it here, and for some miles skirts closely the edge of the wild canyon in which it is enclosed. The walls of the canyon, usually over 200 feet (60·9 m.) in height, show almost continuous exposures of the undulating and in places crumpled and broken, strata of the Hazelton formation. Boulder clays in heavy ridgy sections overlie the older rocks, and are pierced in three placed by tunnels.

**Mile 186.**—A boulder clay plateau, 75 feet (22·8 m.) in height above the grade of the railway, and 300 feet (91·4 m.) above the river level, is pierced by a tunnel 2,016 feet (614·4 m.) in length. Southwest of the tunnel, the deep, winding, rocky gorge of the Bulkley is seen to advantage from the railway grade.

**Mile 188.**—A deep cut exposes the boulder clay at this point. Boulder clays often associated with sands, clays and gravels are prominent in most of the sections along this portion of the valley.

**Mile 190·9.**—Here the deep valley of Mud creek, sunk through boulder clay, is spanned by a high bridge.

**Mile 193.**—Long sections of greyish coarse tuffs and volcanic breccias holding numerous rounded andesitic bombs, occur at this point and are underlaid in places by the dark tufaceous sandstones characteristic of the Hazelton group.

**Mile 193·5.**—The coarse grey fragmentals are cut by an altered andesitic dyke 120 feet (36·5 m.) in width. The dyke probably belongs to the same period of vulcanism as the band of ejectamenta it cuts.

**Mile 193·9.**—The tuffs are overlaid by a massive band of green andesite showing brecciation in places.

**Mile 195·9.**—North of Porphyry creek the green andesitic flow rocks are cut by a white, yellow weathering, altered intrusive filled with pyrite. This rock represents a contact phase occurring at the termination of a large granodiorite stock which extends to the northeast.

**Mile 196·3.**—Sections of green andesite, brecciated in places and occasionally holding greenstone fragments, are exposed at this point.

**Mile 198·9.**—Boulder creek is crossed on a high bridge.

**Mile 202·1.**—The beds of the Skeena formation (lower Cretaceous) occupy a basin extending along the


Canyon on the Bulkley river.

railway from Mile 197 to about Mile 204. Good sections of these beds occur in a railway cut at this point.

The Skeena beds overlie those of the Hazelton formation, apparently comformably, although this has not been definitely proved. They consist of felspathic sandstones, indurated clays, carbonaceous shales, conglomerates and occasional beds of coal. They are folded, but not so severely as the Hazelton beds, and do not show the same persistent fracturing and veining.

**Mile 206·8.**—Looking up the valley of Two Mile creek a good view is obtained of the imposing mass of peaks streaked with snow fields which form the southern end of the Rochers Déboulés mountains. The highest peak reaches an elevation of 8,100 feet (2,468 m.).

**Mile 210.—Moricetown.**—A short box canyon occurs on the Bulkley at this point. The canyon is sunk through a sheet of andesite bent into an anticline. Half a mile beyond Moricetown are sections showing green andesites streaked in places with black areas.

**Mile 213·3.**—Interbanded green and red andesitic rocks of the Hazelton group are exposed here. The green variety represents flow rocks. The red variety consists largely of fine grained andesitic tuffs and in places is cleaved into slate.

**Mile 214·2.**—Sections of the ordinary dark tufaceous sandstones and shales of the Hazelton group occur here. Some of the beds are highly fossiliferous, especially along the Bulkley river a mile east of the railway track, to which point a collecting trip will be made if time permits. The fossil beds so far have only been hastily examined.

The railway at this point passes along a steep slope at an elevation of 190 feet (57·9 m.) above the river, and affords a good view of the rough, partially terraced valley of the Bulkley, here from four to five miles (6·4 to 8 km.) wide. The valley on the east is bordered by a long worn ridge overlooked by the partially snow-clad peaks of the Babine range.

**Mile 214·4.**—The Hazelton beds here are intruded by a small light coloured quartz porphyry stock.

**Mile 214·5.**—Beyond Trout creek the river bends to the east and the railway follows up Toboggan creek, a small stream fed from a glacier in the Hudson Bay mountains, the bordering range west of the valley. The valley in this portion of its course is covered thickly with

drift, mostly boulder clay, and few rock sections are exposed.

**Mile 225.**—Kathlyn lake, a shallow sheet of water about a mile in diameter occupies a depression in the boulder clay. To the west are three prominent peaks of the Hudson Bay mountains separated by deep valleys filled in their upper reaches with ice.

Southeast of Kathlyn lake, the railway follows a boulder clay plain separated from the river by a low ridge.

**Mile 230.**—At this point the railway rejoins the Bulkley river, which it follows to Telkwa. The Bulkley here winds through a wide secondary valley sunk through the drift and bottomed with large alluvial flats.

**Mile 235·51.—Telkwa.**—The Telkwa river, a swift turbid glacial stream, here joins the clear Bulkley. Both streams approach their point of junction through short canyons, having sunk their channels through the drift into a low rock plateau, probably a ridge in the floor of the old valley.

Sections of the bluish grey, felspathic sandstones and carbonaceous shales of the Hazelton group are exposed along the canyons.

Telkwa the terminal point of the excursion is situated east of the Bulkley river opposite the mouth of the Telkwa river.

## EXCURSION C 8.

# YUKON AND MALASPINA.

CONTENTS.

# GENERAL INTRODUCTION

BY

D. D. Cairnes.

Excursion C 8 includes the trip from Prince Rupert to Skagway, Whitehorse, and Dawson, and the return journey via Skagway, Juneau, Glacier bay, Yakutat bay, and Prince Rupert to Vancouver.

The trip from Prince Rupert to Skagway, along the fiord-indented, island-strewn coast of southeastern Alaska is most picturesque. The effects of glaciation, past and present, are there strikingly illustrated, and toward the north a number of glaciers extend to the water's edge and may be viewed at close range from the steamer. The distance from Prince Rupert to Skagway is about 460 miles (740 km.).

From Skagway to Whitehorse, a distance of 110 miles (177 km), the journey is made by the White Pass and Yukon railway. From Skagway the train commences almost immediately, a steady climb up the wild, rugged, granitic mountains of the Coast range, proceeds over the White Pass summit, thence runs along various small lakes and streams to Lake Bennett, and continues along its shores to Caribou, 68 miles (109 km.) from Skagway. For this distance, the train follows very closely the general route pursued by the early stampeders in their mad rush to the Klondike in 1897 and 1898. From Caribou northward the train follows a broad depression for about 30 miles (51 km.) until suddenly Lewes river comes into sight from the east and a good view is obtained of the famous Miles canyon, where so many daring adventurers have lost their lives. The railway in the last few miles has a steep grade, descending rapidly to the banks of Lewes river at Whitehorse, near which are situated the Whitehorse copper deposits.

From Whitehorse to Dawson the journey is made by steamer down Lewes and Yukon rivers, a distance of about 460 miles (740 km.). This trip, made on one of the commodious steamers plying these waters during the summer months, is one of exceptional beauty and is of particular

interest to the physiographer and glacial geologist, as in this distance one passes gradually from a region near the inner edge of the Coast range where glaciation has been intense, well out into a portion of the Yukon plateau where no evidence of glacial ice can be detected. Among the more interesting points or features along the route are Lake Laberge, Thirtymile river, Tantalus coal mine, Five Fingers rapids, and Rink rapids.

After spending three days in the vicinity of Dawson, in the Klondike gold fields, the excursion will return to Skagway. Stops have been arranged along the route to allow the excursionists to visit Tantalus coal mine and Whitehorse copper deposits.

From Skagway to Juneau, a distance of 125 miles (200 km.) the journey must be made by steamer, and while at Juneau facilities will be afforded for visiting the great Treadwell mine in the vicinity.

From Juneau members of the excursion may either return to Vancouver or continue northwesterly along the Alaskan coast to Yakutat. Those proceeding to Yakutat will spend two days in Yakutat bay, where they will have an opportunity of studying existing glacial phenomena, among them the great Malaspina glacier and the deposits being formed in places along its front, and will be able to see clearly from the steamer the various other important ice bodies along the coast between Juneau and Yakutat.

The return journey from Juneau to Vancouver will follow, as on the way north, the picturesque inland passage along the coast.

For convenience in description, C 8 excursion is divided into three sections as follows:—

1. Prince Rupert–Skagway section.
2. Skagway–Whitehorse–Dawson section.
3. Juneau–Yakutat section.

The descriptions of C 8 excursion are arranged under the above headings.

# PRINCE RUPERT—SKAGWAY SECTION

BY

FRED. E. WRIGHT.

## PHYSIOGRAPHY AND GEOLOGY.

The geologic and geographic features which are characteristic of the coast from Vancouver to Prince Rupert continue northwestward with slight change to Skagway. To the east, the Coast Range batholith or batholiths extend in an unbroken line from Vancouver northwestward for over 1,000 miles (1,600 km.) and average nearly 100 miles (160 km.) in width. The major structures of the intruded rocks follow the trend of the Coast range, especially from Wrangell to Skagway. The geology throughout the region is on a broad scale, the different formations often continuing for many miles either without perceptible change or with a continuous and progressive change which can be readily followed.

The island group along the coast, which constitutes the Alexander archipelago, is considered to be the southerly extension of the Mount St. Elias range, while the shore of the mainland belongs to the western flank of the Coast range. This separation by Brooks of the island group from the mainland is in accord with the classification of Dawson in British Columbia, where the Vancouver range is clearly distinct from the mainland Coast range. Although rugged and mountainous in the extreme, this portion of southeastern Alaska is so profoundly intersected by narrow arms of the ocean that communication by water between nearly all parts of the region is feasible and easy. This web of waterways, spread over the entire area, affords deep sea craft access to points far inland, and is of great economic importance. The fiords are not only of value as highways of commerce, but they are a great commercial asset because of the immense quantities of fish—salmon, halibut, and herring—which throng their waters at different seasons of the year. The peculiar and unusual combination of deep narrow fiords and high towering mountains, heavily covered along their bases with dense forests of spruce, hemlock, and cedar, in contrast to their glacier and snow-clad peaks and domes, produces tremendously impressive scenery, and appeals alike to traveller and native

To the former, however, the abundance of rain in this region is an inconvenience and often depressing, but, once this condition is accepted, the superb scenery is in itself ample reward for the journey.

The characteristic surface features of this belt are its coasts, its fiords, its valleys, its drainage, its glaciers, and its mountains. The coasts are irregular in outline and generally abrupt and mountainous even to the water's edge. Occasionally, however, low lying forelands fringe the base of the mountains, as at Gravina island, and often extend as a reef for some distance from the shore, where they become a menace to navigation. In the Glacier Bay region submerged tree trunks prove that the coast is sinking relatively to sea level, while on Admiralty island recent fossils have been found in a bed of blue clay 200 feet (60 m.) above tide water, thus indicating a rise of the coast since the recession of the ice. It would appear, therefore, that the coast has undergone both positive and negative changes since the Glacial epoch. The coasts are generally heavily covered with dense forests which, notwithstanding the lack of proper subsoil which was entirely removed by the ice, are so thick and luxuriant that the geologist is forced to confine his reconnaissance study of the region to the immediate shore outcrops between high and low tide water marks and to the uplands above timber limit, 2,000 to 3,000 feet (600 to 900 m.) above tide water. The fiords are deep and are characteristically trough-shaped, Their flat floors are in places cut below grade in their central portions and relatively shallow near their mouths, and are soft and evidently covered with glacial débris. The best halibut fishing is found on these terminal submerged sandbanks. Many of the fiords are remarkably straight and trend either in a northerly or a northwesterly direction. The longest fiord is Chatham strait with its inland extension, Lynn canal. It is about 250 miles (400 km.) long, 3 to 6 miles (5 to 10 km.) broad, with a depth of 1,000 to 2,500 feet (300 to 750 m.), and traverses the general trend of the bed rock structure at an angle of about 30 degrees. Both the topography and geology indicate that it owes its position to a great structural fault. Many of the other fiords also follow structural lines in the bed rock formations. Other important fiords are Portland canal, Clarence strait, Behm canal, Taku inlet, Glacier bay, Icy strait, and Cross sound. The evidence at present available indicates that practically all the fiords are simply

old valleys which, during the ice-flood period, were profoundly modified, the glacial erosion extending far below sea level, widening the valley, aligning its walls, and smoothing them out into wide sweeping curves; in brief, sculpturing the land into forms in harmony with the stiff, non-pliable nature of the eroding ice streams confined within the valley. As a result, the topography bears everywhere the marks of most intense glaciation. Of the distinctive features of glacial erosion on a tremendous scale, the following are characteristically developed in Southeastern Alaska:—U-trough shape of cross section of valley; straightening of valley course; glacial grooves and markings along valley sides and bottom;; steep valley head, often with cirque termination; hanging valleys; steep valley walls, in places overhanging and showing double slopes; alignment of cliff bases; glacial junction spurs; grade of valley floor, in places overdeepened; knolls of bed rock projecting above the valley floor; roches moutonnées, etc. The noticeable absence of moraines in this area of intense glaciation is due chiefly to the peculiar steepness of the mountain and valley slopes, which are often oversteepened and so uneven, that, except for the river deltas and flats, it is difficult to find a flat area a single square mile in extent in all the 40,000 square miles (100,000 sq. km.) of land area in Southeastern Alaska.

The fiords pass at their heads over broad tidal flats into wide floored valleys, densely forested, and exhibiting everywhere profound ice erosional features. The valleys in turn are usually terminated by cirques in which a small glacier may still be present, the original glacier, which filled the valley to a depth of 4,000 to 6,000 feet (1,200 to 1,800 m.) having dwindled to the present miniature glacier, which is ineffective and incapable of accomplishing the prodigious feats of erosion which it performed during the ice deluge. Farther to the north and west, in Glacier bay and Yakutat bay, the glaciers are larger and more impressive, but, compared with the great ice masses which were active during the period of maximum ice extension, they are mere pigmies. The land forms over the entire area indicate an intensely glaciated region which has been but slightly modified by water erosion since the Glacial epoch. At the time of maximum ice flooding, the ice sheet covered the whole archipelago with the exception of isolated high peaks, which can be recognized at present as having been above the ice sheet, by their sharp serrated

outlines and lack of glacial rounding. The sand banks off the coast indicate that the ice extended even on and into the ocean for some distance from the coast.

Rivers and streams are abundant in this region, and, although in general short and draining relatively small areas, they are of large volume during the summer months because of the excessive precipitation and the melting of the snow in the mountains. Several of the rivers, notably the Stikine, Taku, Chilkat, and Alsek, rise in the interior plateau country beyond the Coast range and are evidently antecedent to it in character. The Stikine river is navigable up to Telegraph Creek, British Columbia, 170 miles (273 km.) from the coast. Most of the rivers enter salt water at the head of a fiord, but many streams from tributary hanging valleys terminate as waterfalls, plunging 1,000 feet, (300 m.) more or less, down the walls of the master valley and adding greatly to the charm of the landscape. Many of these waterfalls are the outlets of lakes hidden behind the bed-rock lip of the hanging valley, and such streams may well serve later on for the commercial development of power for different purposes.

Southeastern Alaska is essentially an upland area of high relief, deeply dissected by valleys and canyons. The uplands slope in general toward the Pacific, and exhibit in places a tendency toward uniformity of their summit levels, which there have the appearance of an uplifted, warped, and much incised base level of erosion. They have been so interpreted, but there are certain objections to this simple hypothesis of an elevated peneplain which have not been entirely removed and will have to be met before it can be finally accepted. It is possible that both the observed tendency toward planation in the uplands and also in the forelands noted above, owe their present character to ice action. It is significant in this connection that the upper limit of ice action coincides with the upland base level. If the ice sheet remained long enough at approximately the same level its surface might well have functioned, like a large water surface, as a datum plane toward which the exposed land masses tended to be bevelled. Sufficient evidence has not yet been gathered to determine definitely the role, which such ice-cap beveling may have played in the formation of the observed upland surface.

The structure of Southeastern Alaska is exceedingly complex, and has been studied at relatively few points.

It includes rock formations representing nearly all the geologic periods from early Paleozoic to the present. The Paleozoic rocks have passed through several periods of folding and metamorphism, and show clearly the effects of such treatment. They are in places so intensely metamorphosed and intricately folded, that it is not possible to disentangle all the details of their structure; even to decipher their broader features is in many instances not easy. In general the formations strike parallel with the northwest trend of the mountain range, and this produces a zonal arrangement of the broader features of the areal geology. In the different formations, we find interbedded with one another, black slates, argillites, greywackes, crystalline schists, crystalline limestones quartzites, greenstones, and chlorite- and amphibole-schists. The intrusive rocks consist chiefly of granular diorite and granite types. They constitute the great batholithic core of the Coast range, and dominate it both structurally and petrographically. They also cover large areas in the central portions of many of the islands.

The Coast Range batholith is bordered on the west by a band, several miles wide, of closely folded crystalline schists, composed largely of Carboniferous and Mesozoic strata. They have been termed the Ketchikan series by Brooks in the Ketchikan district, while in the Juneau district they are grouped together as the "schist band" by Spencer. They have been traced from the southern boundary of Southeastern Alaska to its northern boundary at the head of the Chilkat basin. These strata are essentially siliceous mica-schists and argillites, feldspathic schists with intercalated amphibole—and chlorite—schists, and occasional belts of crystalline limestone containing Carboniferous fossils. Narrow outlying belts of the Coast Range intrusives invade these schists and have often altered and recrystallized them to such an extent near the contacts that they are now massive gneiss, and it is not everywhere possible to distinguish with certainty the boundary line between the intrusive and the intruded rocks. This is especially true along the margin of the mainland Coast Range batholiths, where, in addition to gneissoid structure, the rocks are cut by an intricate network of pegmatite dykes and quartz veinlets. In the Ketchikan district this type of contact prevails, the effect of the intrusive extending often for 10 miles, (16 km.) and more out from the contact. Away from the contact, the

beds become less schistose, and "black slates" intruded by altered dykes of andesitic and gabbroic rocks, predominate. The latter are more prominent in the Juneau district than to the south. At a distance from the Coast Range batholith, intercalated beds of altered lavas and tuffs, usually called greenstones appear; still farther from the contact great thicknesses of these greenstones occur. Such belts of massive greenstone beds are well exposed along Tongass narrows at Ketchikan, along the west side of Cleveland peninsula, on Glass peninsula, and on the west side of Douglas island.

Beyond this belt and toward the outer coast, the bed rock structure changes with the latitude, and beds of one formation cannot be traced for any great distance northwesterly as can the rocks along the mainland. This is largely due to the irregular island batholithic intrusives noted above.

The sedimentary rocks flanking the Coast Range batholiths in this region are folded closely near the contact and more openly at a distance, so that, though their general trend is parallel to the range, their dip is extremely variable, ranging from northeasterly to southwesterly at all angles. These dips become more constant, however, toward the north in the Wrangell and Juneau districts, where the schists are more typically developed, where mineralization along certain bands is more pronounced, and where sharp and closed and overturned folds appear to be the rule. The prevailing dip there is steeply northeast into the mountains, and the strike parallel with the range.

In Southeastern Alaska the oldest rocks are apparently a series of fragmental rocks, now represented by banded quartzite, chert, sandstone conglomerate, and some tufaceous material. These clastic rocks grade upward into calcareous beds and limestones containing Silurian fauna. The total thickness of these beds is 10,000 feet (3,000 m.) or more. Sedimentation was probably continuous during early Silurian time. Toward the end of the period there was then a gradual deepening of the sea, and several thousand feet of limestone strata were laid down. The oldest member of the Devonian is a succession of conglomerate and sandstone beds composed largely of igneous material, the pebbles of the conglomerate being embedded in a tufaceous matrix and derived chiefly from the older banded quartzite-limestone strata. This series,

which is estimated to be 3,000 feet (900 m.) thick, grades upward with apparent conformity into lower Devonian limestones, the total thickness of which is about 2,000 feet (600 m.) These are followed in certain areas by argillaceous schists and slaty limestones, and these, in turn, by upper Devonian limestone of considerable thickness. The close of the Devonian period was marked by volcanic activity along this coastal belt, and lavas and tuffs to an estimated thickness of about 800 feet (250 m.) were laid down. During the Carboniferous period, limestones and argillites were again formed, and volcanic activity began again in upper Carboniferous times and continued well into the Mesozoic era. Many of the altered massive greenstones and greenstone schists date from this long period. The beds of lava and ash, ejected from the volcanic vents, were contemporaneous with the slate beds, and because of their intimate association with the sediments the volcanics are regarded as submarine intrusives. Their total thickness, including the slates, is estimated at 4,000 feet (1200 m.) During Mesozoic times the sequence of geologic events has not been definitely determined because of lack of proper evidence, and geologists do not agree in their interpretation of the few observed facts. The evidence is at best fragmentary, and indicates that, following the deposition of Carboniferous and early Mesozoic strata, the bedded rocks suffered intense metamorphism and at the same time were highly tilted and intricately folded and rendered schistose, the direction of the axes of folding and of the schistosity being generally southeast-northwest. Immediately following this period, and possibly in part concomitant with it, occurred the invasion of the Coast Range batholiths, whose lines of intrusion are in a broad way parallel to the schistosity and bedding planes of these older rocks. The Coast Range intrusives probably began early in Jurassic times, and continued either to upper Jurassic or lower Cretaceous times. During the lower Cretaceous, calcareous slates were deposited, after which a period of uplift and folding followed. In the early Tertiary, the Kenai (Eocene) coal-bearing beds were deposited in isolated local basins in this region, but they are not of commercial importance. They occur only near sea level and in low-lying valleys and basins practically enclosed by mountains of older rocks. Flat lying Tertiary basalt lava flows occur here and there and attain a thickness of

1,500 feet (450 m.) on Kuiu island. A large part of the Tertiary sediments may have been subsequenly removed by erosion. The next important event in the geologic history was the development of the ice sheet which covered the entire district. Its retreat left the topography in essentially the present form. After the retreat of the ice some basaltic sheets were locally erupted.

In this brief sketch of the geologic history of Southeastern Alaska many details have been omitted, but many more details are still required before the history can be written with even a first approach to completeness. Many of the conclusions reached are still tentative and merely the best that can be drawn from the existing evidence. On the accompanying maps only six subdivisions are recognized, the entire Paleozoic being grouped as a unit; likewise the Mesozoic, the Tertiary, and the Quaternary. It should be noted that the greenstone black slate series apparently includes formations ranging from upper Carboniferous to Jurassic in age. This finds expression in the term "Vancouver series" which is used in British Columbia.

Miles and Kilometres

## ANNOTATED GUIDE.

0 m.
0 km.

**Prince Rupert.**—After leaving Prince Rupert and passing Dundas island on the left, and Port Simpson, 25 miles (40 km.) on the right, the route of the excursion enters Dixon entrance and crosses the International Boundary line into Southeastern Alaska. On the right is Portland inlet and Portland canal, one of the largest fiords on the Pacific Coast. Portland canal cuts almost entirely through the Coast Range batholith and extends practically to its eastern flank. Mineral deposits have been discovered along this eastern contact of the batholith in Canadian territory both at the head of Portland canal and near Observatory inlet. Several bands of sedimentary rocks, included in the Coast Range batholith, are also heavily mineralized and promise well as ore producers.

Dixon entrance is one of the few exposed parts of the inland passage, and at certain times

Miles and Kilometres

of the year is rough and choppy. Once inside of Duke island and in Revillagigedo channel, however, the sweep of the waves and winds is broken, and quiet waters again prevail.

31 m. 50 km **Cape Fox**.—Cape Fox and the adjacent mainland peninsula opposite Duke island consist largely of massive and schistose greenstone beds with occasional calcareous and argillaceous bands. These strata were formed either at the end of the Carboniferous or in the early Mesozoic. At present they are so highly altered that their original character is rarely apparent without detailed study. The same belt, though slightly different in composition, continues northward to Ketchikan and beyond.

62 m. 100 km. **Annette Island**.—Annette island on the left is interesting, because of the development of the forelands which fringe its shores, and which have been considered by Gilbert to indicate a secondary base level of erosion in the physiographic development of this region. Annette island has been set aside as a reservation for the Indians at Metlakatla under Rev. Duncan.

78 m. 125 km. **Tongass Narrows**.—Along the shore of Tongass narrows, greenstones with interbedded argillaceous and calcareous rocks in various stages of metamorphism are exposed.

80 m. 130 km. **Ketchikan.**—Ketchikan is the centre of the Ketchikan mining district in which copper and gold are the principal metals mined. Mining operations are confined chiefly to Prince of Wales island.

93 m. 150 km. **Clarence Strait**.—Entering Clarence strait the route continues northward to Zarembo island. 161 miles (260 km.) whence it passes across Sumner strait into Wrangel narrows.

186 m. 300 km. **Wrangel Narrows.**—At the entrance to the narrows the shores are composed largely of greenstones, which, however, soon give way to black slates and calcareous beds.

208 m. 335 km. **Petersburg.**—After passing Petersburg the course enters Frederick sound and approaches the mainland, where the metamorphic influence

Miles add
Kilometres

of the Coast Range batholith is clearly expressed in the sedimentary rocks (argillites and schists) outcropping along the shores. Pegmatite dikes are also more abundant near the batholith contact.

335 m.
540 km. **Juneau.**—Near Juneau the rocks exposed along the shores are greenstones alternating with black slates. Toward the east the greenstones (originally lava flows and tuffs) are less common, and the entire formation consists of black slates in different stages of metamorphism. These slates pass in turn into the highly schistose rocks of the Silver Bow basin. The planes of cleavage, and usually also of stratification, strike northwesterly and dip at high angles northeast into the mountains. Intrusive dykes of diorite and related aplitic rocks occur frequently and are intimately associated with the mineralization in this region. The Treadwell group of gold mines on Douglas island opposite Juneau are located on mineralized diorite dykes intrusive along or near the contact between black slate and greenstones bands. These dykes were much fractured after intrusion, and the fracture cracks were subsequently filled with gold-bearing quartz veinlets. The zone of mineralization here is nearly 400 feet (122 m.) in width and has been traced for over 3,500 feet (1 km.) along the strike. Much of the gold is free milling and is associated with pyrite and some pyrrhotite and magnetite and many other less abundant minerals. The Treadwell group alone has produced nearly $50,000,000 worth of gold and is one of the largest gold mines in the world.

391 m.
630 km. **Lynn Canal.**— Continuing north from Juneau the route enters Lynn canal and gradually approaches the Coast Range batholith. At 416 miles (670 km.), or abour 25 miles (40 km) above Berners bay, the east shore of Lynn canal is bordered by the batholith, which is continuously exposed to Skagway at the head of Taiya inlet and beyond to White pass and Lake Bennett in British Columbia. The elon-

Miles and Kilometres

gated, finger-like peninsulas at the junctions of Chilkat, Chilkoot, and Taiya inlets are typical glacial junction spurs which have resulted from the action of the large valley glaciers confluent at acute angles. The glaciers overrode the junction spurs and cut them to the present elongated shapes, rounded in transverse cross section and almost cigar shaped in plan.

460 m. 740 km. **Skagway.**—At Skagway several different types of the granitic and dioritic rocks occur; the Skagway aplitic and pegmatitic rocks are specially interesting.

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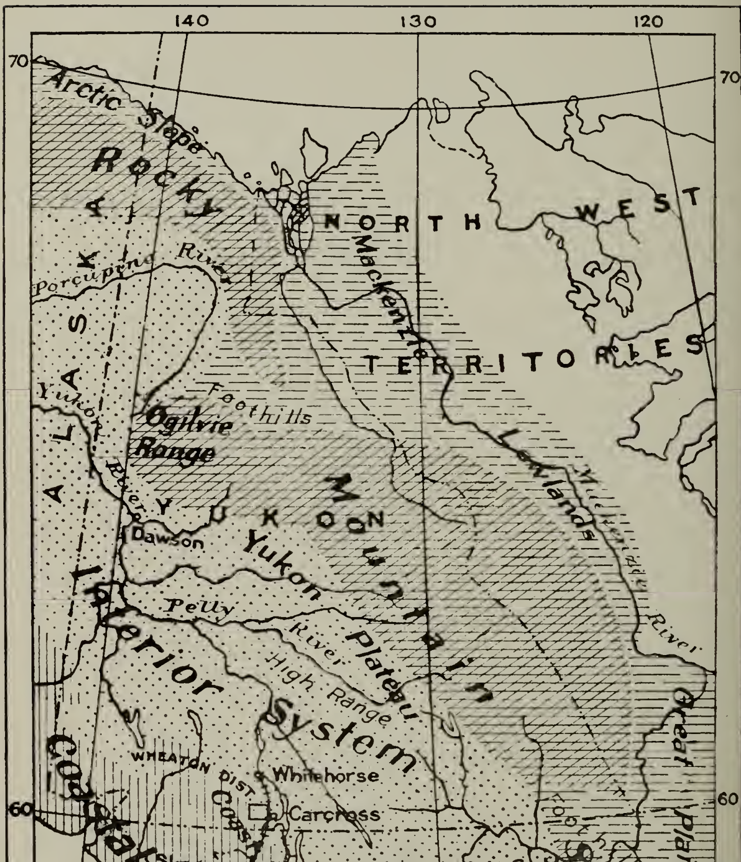
# THE SKAGWAY—WHITEHORSE—DAWSON SECTION.

BY

D. D. CAIRNES.

## GENERAL TOPOGRAPHY AND GEOLOGY.

In going northward from Skagway over the White Pass and Yukon railway, the traveller commences at once to cross the Coast range and reaches its northern or northeastern border in a distance of about 45 miles (72 km). Thence, continuing over the railway to Whitehorse and down Lewes and Yukon rivers to Dawson, 571 miles (914 km.) from Skagway, the journey is within the southwestern and central portions of the Yukon plateau, Yukon river occupying a median position in this physiographic province. The main physiographic systems of Yukon Territory, as well as those of British Columbia to the southeast and of Alaska to the west and northwest, trend in a general way parallel to the Pacific Coast line, following its peculiar curved contour.




Physiographic Provinces of Yukon by D. D. Cairnes.

The Coastal system from about the 50th to nearly the 60th parallel of north latitude embraces only the Coast range, if the islands to the west be considered to form a separate range [**29**, p. 4; **30** pp. 61, 62], but this simplicity is interrupted near the head of Lynn canal, whence northward and northwestward, the Coastal system consists of different ranges, in some cases separated by wide valleys, as well as by other subordinate mountain masses. The Coast range, after following the coast line from Southern British Columbia to nearly the head of Lynn canal, passes behind St. Elias range, and thence northward constitutes the most easterly portion of the Coastal system, becoming gradually less prominent until it merges into the Yukon plateau near Lake Kluane, at latitude 61° and longitude 138° 30′. The Coast range consists, in a general way, of an irregular series of peaks and ridges, that possess but little symmetry other than a rough alignment parallel to a northwesterly-trending axis. The range has everywhere a precipitous and jagged aspect, and consists largely of knife-edged crests, rugged or even needle-like summits, and sharply-incised valleys. The summits in the vicinity of the White Pass and Yukon railway rise to altitudes of 5,000 to 6,000 feet (1,500 to 1,800 m.) above sea-level, and on account of a certain uniformity of summit level, which bears no relation to structural features, this terrane has been considered by a number of geologists [**33**, p. 128; **66**, p. 132; **6**, pp. 286-290; **293**] who have studied it topographically, to represent a peneplanated or at least a mature to old surface of erosion, subsequently elevated. As mentioned in the Prince Rupert—Skagway section, however, the evidence on this point does not appear to be conclusive, and the uniformity of summit level may be the result of various other causes.

Bordering the Coastal system along its inland edge, and stretching thence eastward, northeastward, and northward to the Rocky Mountain system is the great Interior system of plateaus and mountains, the most northerly member of which, the Yukon plateau, has a width in Northern British Columbia and Yukon of 250 to 300 miles (400 to 480 km.). In places some well defined ranges or groups of mountains lie within this plateau province.

Into the upland surface of the Yukon plateau in Southern Yukon, the main drainage courses have incised channels varying from 3,000 to 4,000 feet (900 to 1,200 m.),

producing thereby a very irregular topography. The summits of the unreduced hills and ridges, lying between the waterways, mark a gently rolling plain which slopes toward the north and northwest. The plateau is best seen from a summit that stands at about the level of the upland, where the observer will be impressed with the even sky-line, sweeping off to the horizon and broken only here and there by isolated, residuary masses rising above the general level. This plain, however, bears no relation to rock structures, erosion having bevelled the upturned edges of the hard as well as the soft strata. The surface, consequently, is entirely discordant to the highly contorted, metamorphosed rocks that make up much of the plateau.

Along the northern portion of the Coast range, the general summit of this terrane merges into that of the Yukon plateau in a manner suggesting the synchronous planation of these two provinces,—a view that is held by Brooks [**6,** pp. 286-290, 293], Spencer [**67,** p. 132], and others. The various vertical movements that have affected these terranes, however, whether the Coast range was planated or not, have been such that the uplift has been greatest along the axis of the Coast range and least along that of the Yukon plateau, so that the latter possesses the contour of a huge flaring trough whose median line is in a general way, marked by the course of Yukon river from its headwaters in Northern British Columbia to Bering sea.

As topographic features are often to a certain degree merely expressions of the bedrock structure and composition, it might be expected that the same general geological terranes would extend through Alaska, Yukon, and British Columbia, following the general trend of the coast line, and to a limited extent this has been found to be true. In Yukon, however, this parallelism, and to some extent conformity of geological formations to the physiographic provinces, is most apparent when the entire territory is considered. The Coast range everywhere consists almost entirely of the granitic materials composing the great Coast Range batholith, and the various geological terranes of the Rocky Mountain system have a decided general trend parallel to its physiographic boundaries. In the Yukon plateau, however, the different geological formations are somewhat irregularly distributed and have no marked trend parallel to the borders of the plateau province.

As mentioned above, the rocks composing the Coast range are dominantly granitic in character, and although mainly granodiorites, they range from gabbros to granites. They were intruded at different times, commencing early in the Jurassic and extending probably up into the Cretaceous. The geological terranes of the Yukon plateau in Southern Yukon, range in age from apparently Pre-Cambrian to Recent, and include sedimentary, igneous and metamorphic members.

The succession of geologic events in that portion of Yukon plateau included in Southern Yukon and Northern British Columbia, and particularly that portion traversed in journeying from Skagway to Dawson, will now be presented in so far as they are known. The information available, however, is rather fragmentary, and for long periods the records have been almost or entirely destroyed. Still it is hoped that a brief treatment of the data obtainable will give a general idea, at least, of the various vicissitudes which the district has undergone.

The oldest records are contained in a group of rocks, partly igneous and partly sedimentary, which consist dominantly of schists, gneisses, and some impure limestones. These rocks are extensively developed in the vicinity of Dawson and elsewhere in Yukon, and have given rise to the famous placer gold deposits of the Klondike and other districts. These rocks have been generally considered to be of early Paleozoic age, but recent investigations by the writer [**20, 21**] tend to show that they are in part or entirely Pre-Cambrian in age. These rocks show that there were accumulated at an early stage in the history of the district, thousands of feet of arenaceous and argillaceous matter, followed also by great thicknesses of calcareous material, and that vulcanism was active during and after sedimentation. The relative ages of the various members are imperfectly revealed, since all are now greatly metamorphosed, plicated, distorted, and eroded and appear as a group of rocks consisting dominantly of sericite-schists, chlorite-schists, actinolite-schists, quartz-schists, mica-schists, schistose amphibolites, mashed and sheared diabases, greenstone-schists, quartzites, gneisses, and impure limestones.

Parts of Yukon Territory appear to have been inundated by the sea from early Cambrian to late Carboniferous time, during which time, calcareous sedimentation was apparently continuous. From Dawson southward, how-

ever, the records are very indistinct from the period at which the older schistose rocks were formed until late Silurian or Devonian times when a great portion of the district was involved in a widespread dynamic revolution, which caused extensive deformation and metamorphism and was accompanied by considerable volcanic activity. At the close of this disturbance a considerable area was above the sea and a long erosion interval ensued. Some time before the middle Devonian, however, a great part of Yukon sank beneath the sea, and at about that time vulcanism became active at a number of points. The older pyroxenites and andesitic members of the Perkins group are thought to have been intruded at that time.

This sea invasion prevailed at least well into the Carboniferous, and several thousand feet of calcareous, siliceous, and argillaceous sediments, now represented by quartzites, cherts, slates, and limestones, were deposited. The limestone hills, ridges and ranges, that are now so prominent along Tagish lake, Lewes river, Lake Laberge, and elsewhere, are the result of this period of deposition. Sedimentation was brought to a close by a widespread deformation, and at about this time vulcanism became active, and andesitic rocks invaded the district and buried extensive areas under flows and tufaceous accumulations.

In Jurassic—apparently early Jurassic—time an extensive crustal movement occurred which was accompanied by the injection of vast amounts of igneous materials, including the earlier of the great batholiths of the Coast range. These batholiths constitute probably the largest exposed post-Paleozoic intrusive masses in the world, and afford unexcelled opportunities for the study of batholithic intrusions on a tremendous scale.

A considerable area was above the sea at the close of this disturbance, and what was probably a short period of erosion ensued. This was followed by a gradual sinking of the land in Jura-Cretaceous time, which continued until an extensive land mass was submerged.

The materials accumulated in this Jura-Cretaceous sea were chiefly such as have produced upon consolidation, arkoses, conglomerates, sandstones, shales, and coal seams. These rocks have an aggregate thickness in places of over 6,000 feet (1,800 m.) and nowhere has the original top of the series been discovered, the uppermost beds having now been removed by erosion. All the bituminous and anthracitic coals of Yukon were deposited during this period.

This Jura-Cretaceous period was also characterized by intense volcanic activity, the evidence of which is recorded in the great amount of ash and volcanic breccia intercalated with the normal sediments and in places even exceeding them in amount. In places, dykes are numerous and flows are extensive, and everywhere the volcanics of this period appear to be andesitic in character. Vulcanism persisted until after sedimentation had ceased, and along Nordenskiöld river great masses of these andesites occur overlying eroded surfaces and edges of the Jura-Cretaceous sediments.

A widespread deformation terminated the Jura-Cretaceous period of sedimentation, at the close of which a considerable land mass, comprising the greater part of southern Yukon at least, was above the sea. Degrading action followed, and from that time to the present there is no evidence to show that any portion of the district between Skagway and Dawson has been submerged beneath the sea.

Following this Jura-Cretaceous disturbance, and mainly, it is thought, during Tertiary, but possibly extending into Pleistocene time, the district was subjected to several volcanic invasions. As a result of what appears to be the oldest of these invasions, basalts pierced the older formations and flowed over the land surface, and in places, hundreds of feet of basalt-tuffs accumulated. The basalts exposed in Miles canyon, along Lewes river below Tantalus, and along the river above and below Selkirk, all belong to this period. Along Nordenskiöld river near Carmack, the basalt-tuffs have their greatest known development. About this time, dykes of granite-porphyry, syenite-porphyry, and rhyolites invaded the older formations, and rhyolites also flowed over the land surface, generally in thin sheets, and in places were accompanied by great amounts of related tuffs and breccias. To the north and especially in the vicinity of Indian river, diabases and andesitic rocks occur intimately associated with sediments considered to be of Eocene age.

In upper Cretaceous time a transgression of the sea took place along the present Yukon basin and also probably extended to other portions of Alaska and Northern Yukon. Deposition continued well into the Eocene, although in the upper Yukon basin the Eocene is represented only by fresh water beds which seem to have been laid down in isolated basins. The Kenai lignite-bearing beds of the Rock Creek coal area, which extend along the east side of Yukon river

for 70 miles (110 km.) below Dawson, as well as all the other Tertiary areas of lignite-bearing beds belong to this period of deposition. Developments of similar sediments associated with diabases and andesitic and rhyolitic volcanics occur in the vicinity of Indian and Fortymile rivers, within a few miles of Dawson. These are the most southerly of these Tertiary sediments developed in Yukon or in the district between Dawson and Skagway.

In Eocene or Miocene time, a gradual uplift occurred which, though of an orographic character, was accompanied by volcanic activity and by a considerable local disturbance of Eocene beds. The exact date of this orogenic movement is somewhat in doubt. Dawson [**30**, p. 79] refers the uplift to the Eocene, but Brooks [**6**, pp. 292, 293] has produced considerable evidence to show that the dynamic revolution occurred during late Eocene or early Miocene time. A long period of crustal stability ensued, during which what is now the Yukon plateau as well as, in the opinion of some geologists, the Coast range and other adjoining tracts [**67**, pp. 117, 132] were reduced to a nearly featureless plain which was subsequently elevated. Dawson [**29**, pp. 11-17] maintains that the planation was accomplished during the Eocene epoch, and that the Miocene was a period of vulcanism, deposition, and accumulation, and agrees with Brooks [**6**, pp. 290, 292, 293] in considering that the subsequent uplift occurred in Pliocene or early Pleistocene time. Spurr, however, shows that the erosion of the Yukon plateau was contemporaneous with the deposition of the Miocene strata in the lower valley of Yukon river and, therefore, urges that the Yukon plateau was planated in Miocene time and subsequently uplifted in late Miocene or early Pliocene time. [**70**, pp. 260, 262, 263]. From the information available, however, it seems probable that the Jura-Cretaceous sediments were largely deformed by the Eocene or Miocene (post-Laramie) dynamic movements; that the district was peneplanated during Eocene or pre-Pliocene post-Eocene time; and that this planated tract was uplifted to practically its present position during the Pliocene epoch.

During the long period of crustal stability previous to this last important uplift the topography was reduced to the form of a broad and gently undulating plain, and only occasional unreduced hills and ridges remained projecting above the general level. This lowland surface

then became elevated, and the streams of the district were thus given renewed life and erosive powers, and consequently immediately commenced sinking their channels in the uplifted peneplain. Soon, numerous, deep incisions were carved, which intersected the region in various directions. The interstream areas became more and more individualized, and assumed gradually the aspect of separate mountains and ridges.

The uplift of the Yukon plateau and adjoining tracts was of a differential character, and so conditioned that the resultant topography had the contour of a broad shallow trough, the approximate axis of which is marked by the present position of Yukon river and its main tributary the Lewes, while the Coast range lies along its western or southwestern rim.

The higher tracts, including the ranges of the Coastal system, during the Pleistocene, became the gathering grounds for glaciers, and huge tongues of ice moved down the sides of the Coast range both seaward and inland. These valley-glaciers accentuated the topography produced by uplift and subsequent erosion, and deepened and broadened the depressions they occupied, steepened the valley walls, and sculptured the land forms in a manner characteristic of ice action. Vast amounts of morainal and other materials were carried southward to the Pacific, and northward on the way to Bering sea. The floors of the main valley bottoms of Southern Yukon are deeply covered with these deposits. Distinct ice markings occur along the valleys of Lewes and Nordenskiöld rivers nearly to Tantalus, and are claimed to have been found a few miles below this point. All traces of the presence of glacial ice vanishes, however, long before Dawson is reached.

After the retreat of the ice the topography was virtually that of to-day. The master-streams have been since engaged in removing the burden of glacial sands, gravels, clays, and silts from their valleys and have not as yet succeeded in trenching their channels to bedrock.

A thin veneer of Recent materials forms the surface nearly everywhere. This consists mainly of sands, gravels, clays, and silts of the present waterways, ground-ice, muck, volcanic ash and soil. The volcanic ash is an interesting feature and occurs as a layer of pumiceous sand ranging in thickness from less than an inch (25 mm.) to over 2 feet (·6 m.) This material is noticed as far south as Lake Bennett, where near Caribou it is about an inch

(25 mm.) thick, but it increases in thickness to the north and west for over 200 miles (320 km.). It is calculated that this covers about 25,000 sq. miles (64,800 sq. km.) and has a volume of at least a cubic mile. (4 cu. km.). It is remarkably homogeneous and of more recent age than the silts which are the latest of the glacial deposits. In fact, this ash has fallen since the present waterways have cut their courses to approximately their present depths, and the trees and vegetation are rooted in it. On account of its even distribution, it appears to have fallen very tranquilly and continuously, since in it, as originally deposited, no intercalated layers of foreign materials exist. Mt. Wrangel is the nearest known volcano that is at present active, and as the ash appears to increase in that direction, this or some yet undiscovered volcano in that vicinity is probably the source of the material.

## CLIMATE, FAUNA AND FLORA.

As no description of Yukon would seem at all complete without some mention of climate, flora and fauna, these will now be very briefly considered [**45**]. The climate and vegetation of the southern slope of the Coast range north of Skagway, are similiar to those of other parts of South-eastern Alaska, and have been described in other sections of this guide-book, so will not be further mentioned here.

The climate of Yukon has been, and by many people still is greatly misunderstood. In fact until recently this territory has been popularly believed to be a region extremely difficult of access, and covered by almost perpetual snow and ice. Winter photographs, sensational newspaper descriptions of the Chilcoot pass and the building of the White Pass and Yukon railway, and stories, generally exaggerated, of the privations suffered by those who joined in the early rush to the Klondike are mainly responsible for these opinions.

Now, since the building of the railway over the White Pass summit, and since lines of steamers have been placed on some of the lakes as well as on Yukon river and its main tributaries, the district has come to be better and more favourably known.

The climate of Southern Yukon (south of Dawson) is, during the summer, particularly delightful. On account

of the northern latitude, there is almost continuous daylight during June and July; and for five months, typical warm summer weather prevails. The amount of rain varies greatly in different localities according to elevation and proximity to mountain ranges.

The rivers generally open early in May, but the ice remains on some of the lakes until the first week in June. Slack water stretches freeze over at any time after the middle of October, but during some seasons, the rivers remain open until well into November.

The climate is in a general way similar to that in many parts of British Columbia and other northerly mining camps in the world and few more difficulties have to be met there, in actual mining operations, than in localities farther south. At least six months in each year are suitable for surface working and for the necessary outside operations contingent to mining. Further, during part of the summer, outside work can be continued by night as well almost as by day without the aid of artificial light. The ground is in most places permanently frozen to varying depths, but this does not interfere with mining operations, except while such are being conducted at or near the surface, and in underground placer mining the frost is often an advantage, as when the ground is frozen timbering is not necessary.

The forests of Southern Yukon are nowhere as heavy or dense as those of more southerly latitudes, still in most of the valleys and on many of the slopes up to an elevation of 3,000 to 4,000 feet (900 to 1,200 m.) above sea-level, there is a fair growth of useful timber. On the hillsides the trees become dwarfed near timber line and there give place to shrubbery. The higher elevations are moss-covered or bare.

The forest consists chiefly of 12 or 13 species, 8 of which attain the dimensions of trees. These are the white spruce, *Picea alba*, black spruce, *Picea nigra*, balsam fir, *Abies subalpina*, black pine, *Pinus Murrayana*, balsam poplar, *Populus balsamifera*, W. balsam poplar, *Populus trichocarpa*, aspen poplar,*Populus tremuloides*, and white birch, *Betula alaskana.*

Several varieties of wild fruits grow very abundantly, and many of the wide, flat, extensive valleys are covered with luxuriant growths of wild grasses. Also many varieties of vegetables grown at Dawson, Whitehorse and intermediate points compare favourably with those imported. Moreover, it is well known that horses winter safely in


A sled load of lake trout caught at Tatalamana lake, 30 miles east of Minto on the W. P. and Y. railway.

many of the valleys without being fed. In fact extensive portions of Yukon are considered to be very suitable for stock-raising and agricultural purposes. The great abundance of beautiful flowers in the gardens at Dawson are always a source of wonder to those unfamiliar with the district.

Moose, caribou, sheep, and black, brown, and grizzly bears are plentiful in many districts, as well as many varieties of valuable fur-bearing animals. The streams and lakes nearly everywhere abound in fish, chiefly, grayling, whitefish, lake-trout, pike and salmon.

## ANNOTATED GUIDE.

0 m.
0 km. **Skagway**—Altitude 0. ft. Leaving Skagway the train begins almost immediately a steady climb over the mountains of the Coast range, and in most places the granitic rocks of the Coast range batholith are well exposed. The railway zigzags up the precipitous mountain sides, passing the hanging rocks at Clifton, and rounding one point after another where huge masses of rock have been blasted away. Looking down hundreds of feet below the track, in places, can be seen the foaming, rushing Skagway river, and the old trail over which so many men struggled in their mad rush to the Klondike before the building of the railway. Still ascending, the train passes through the tunnel, thence over the steel cantilever bridge 215 feet (65 m.) above the bottom of the canyon. Everywhere the smoothed, polished, naked rock surfaces, the precipitous-sided U-shaped valleys of the larger streams and the hanging valleys of their tributaries are evidence of intense glaciation. The scenery here is wild and rugged in the extreme.

*.19.7 m.
31.5 km. **White Pass**—Altitude 2,887 ft. (878 m.) The White Pass summit of the Coast range is on the boundary between United States and Canadian territory and the train here passes from

*The distances and elevations between Skagway and Whitehorse have been kindly furnished by the International Boundary Survey department, Ottawa, and the figures are the results of observations made by Mr. Douglas Nelles, D.L.S., 1908-1910.

Skagway, Alaska.

Alaska into British Columbia. The character of the scenery changes rapidly to the north of the summit, becoming less rugged as the Yukon Plateau is approached. Leaving the summit the train runs along various small lakes and streams to Lake Bennett.

39.7 m. **Bennett**—Altitude 2,158 ft. (656 m.). At
63.5 km. Bennett near the head of Lake Bennett, a stop is usually made for luncheon. Continuing, the train runs along the shores of the lake for 27 miles (43 km.), the scenery being particularly beautiful. About 31 miles (50 km.) from the summit, the 60th parallel of latitude is crossed, which is the boundary between the provinces of British Columbia and Yukon Territory. The typical Coast Range intrusives continue along the railway to a point about 11 miles (17 km.) from Caribou, thence for 6 miles (9.6 km.) porphyrites, andesites, basalts, tuffs, and tufaceous sandstones and shales of Jura-Cretaceous age outcrop along the railway. Thence for about a mile, quartzites, slates, and limestones, thought to be of Devonian age, are developed. Typical granodiorites continue to Caribou.

Lake Bennett and other similar bodies of water forming the headwaters of Yukon river, are of particular interest, and various theories have been advanced to account for their origin. It appears, however, that these lakes represent the positions occupied by the last great tongues of the retreating valley glaciers, and that the ice melted so rapidly toward the last that the depressions it occupied had not time to become filled with glacial débris as did other valleys and other portions of these valleys.

The valley of Lake Bennett, which is really a southern continuation of the broad depression extending northward from Caribou toward Whitehorse, is typically U-shaped, has high precipitous walls rising abruptly from the water's edge in places, and, particularly along the western side of the lake, has had all projecting points and spurs planed away by northward moving valley glaciers. Virtually all the


Caribou (Post Office name is Carcross), on the White Pass and Yukon railway.

tributary streams entering this valley have hanging valleys, and in general the effects of valley glaciation are here so pronounced as to make it an ideal region in which to study these phenomena. [**17**, p.p. 11--23].

The terraces seen along Lake Bennett at various elevations possess considerable interest, particularly as similar terraces characterize almost all the main valleys not only in Central Yukon but in adjoining portions of British Columbia and Alaska. They are well developed along Lewes river below Whitehorse, along Lake Laberge, along Nordenskiöld river, and elsewhere. A number of theories have been advanced at different times to explain the origin of these terraces, but the majority of such explanations fail when all the known facts and the extent of the region throughout which the terraces occur, are considered. The writer has investigated these in different districts in the Yukon [**17**, pp. 21-23.] and Northern British Columbia [**18**, see section on "Terraces"] and believes them to be all lake terraces formed in post-Glacial times, owing their origin to a temporary damming of Yukon river near its mouth, possibly by ice, and a consequent brief flooding of the entire river system.

66·7 m. **Caribou**—Altitude 2,171 ft. (660 m.) At
106·7 km. Caribou the train crosses, on a swing bridge, a narrow stream of water connecting Lake Bennett and Nares lake. Thence for over 30 miles (48 km.) the railway follows a wide northerly-trending depression, the floor of which is deeply covered with glacial accumulations which are in places hundreds of feet in thickness. Everywhere the valley bottom is characterized by kettle holes and morainal deposits, and has the general appearance of still being almost as the ice left it. About 15 miles (24 km.) north of Caribou, a lake which was originally about 3 miles (4·8 km.) long was partly drained during the construction of the railway, and there splendid sections of the silts, in places exceed-

Shooting Miles canyon.

ing 100 feet (30 m.) in thickness, are to be seen. To the west of the railway, and in most places within a distance of half a mile, Watson river follows an exceedingly tortuous course from near Robinson to Lake Bennett, a distance, as the crow flies, of about 18 miles (29 km.) For this portion of its course, the river is in most places a slow, deep, sluggish stream.

Practically the only consolidated rocks that outcrop at all close to the track along this part of the journey constitute a low sharp ridge running along the west side of the railway 5 or 6 miles (8 to 10 km.) north of Caribou. These rocks are dominantly Jura-Cretaceous conglomerates and sandstones, and in places are decidedly reddish on weathered surfaces.

About 10 miles (16 km.) before reaching Whitehorse, Lewes river comes into view, having broken its way through the high mountain ridge running parallel to the railway on the east. Five miles (8 km.) farther on, the railway swings close to the river at a point near the head of Miles caynon, and from there a splendid view is afforded of the canyon with its walls of Tertiary basalt showing pronounced vertical columnar jointing.

During Pleistocene time, the former channel of Lewes river became filled with glacial débris, causing the stream to become diverted from its former course. After the retreat of the ice, the river had become superimposed on the basalts in the valley and, in rapidly sinking its channel to obtain grade, produced the famous Miles canyon. In shooting this canyon and the Whitehorse rapids below, many men have lost their lives, particularly during the early days of the Klondike excitement and before the construction of the railway.

From the head of the canyon, the railway descends with a steep grade to the town of Whitehorse which is situated at the head of
110 m. navigation on Lewes river, the main tributary
176 km. of the Yukon.

**Whitehorse**—Altitude 2,083 ft. (633 m.)

Miles canyon, as seen from the White Pass and Yukon railway.

# WHITEHORSE COPPER BELT.*

## General Description.

The Whitehorse copper belt is situated in the southern part of Yukon Territory, about 45 miles (72 km.) north of the British Columbia boundary, and extends along the western side of the valley of Lewes river—the principal feeder of the Yukon—for a distance of about 12 miles (19·2 km.) Most of the important mining properties are situated at distances of from 4 to 7 miles (6·4 to 11·2 km.) from the present terminus of the White Pass and Yukon railway at Whitehorse.

The oldest rocks known in the district are limestones referred to the Carboniferous. These have been extensively invaded by Mesozoic andesites and also by plutonic rocks ranging in composition from typical hornblende granites to gabbros. The youngest consolidated rocks in the district are basalts of Tertiary age. All are overlain by Pleistocene and Recent deposits. The ore-deposits are of contact-metamorphic origin and occur dominantly in the limestones near their contact with the granitic rocks; they are also developed in places in the granitic intrusives.

## Particular Description.

Topographically, the main feature of the district, is the great valley of Lewes river. Opposite Whitehorse the valley has a width from base to base of the enclosing hills, of fully 4 miles (6·4 km.) It is bordered on the east by Canyon mountain, a long symmetrical limestone ridge rising to a height of 2,500 feet (760 m.) above the valley bottom, and 4,730 feet (1,438 m.) above the sea. The western boundary is more broken, and consists, from south to north, of Golden Horn, a prominent peak 5,400 feet (1,542 m.) in height; a wide irregular ridge culminating in Mount McIntyre, 5,200 feet (1,581 m.); and Mount Haeckel, 5,318 feet (1,617 m.) in height. These elevations are separated by wide drift-filled depressions, extending across the range.

*The descriptions here given of the Whitehorse Copper belt are mainly summarized from Mr. McConnell's report on the district [59], supplemented by recent observations by the writer.

Whitehorse, the northern terminus of the White Pass and Yukon railway.

The central portion of the old pre-glacial valley is floored with silts and boulder clays, and through these the Lewes has cut the narrow, winding, secondary valley, about 200 feet (61 m.) in width, in which it now flows.

The oldest rocks known in the district are limestones, which are referred to the Carboniferous. These have been broken through and largely destroyed by three distinct igneous invasions. The earliest invasion was by andesites of various kinds. These were intruded, partly at least, in the form of sheets or sills up to 1,000 feet (304 m.) or more in thickness. The second invasion is represented by plutonic rocks, which range in mineralogical composition from hornblende granites to augite syenites, diorites, and even to gabbros. These rocks cover a large portion of the district and may represent an outlier of the Coast Range batholith. The third period of igneous activity resulted in the production of the numerous porphyrite dikes now found cutting indiscriminately across limestones, granites, and older andesites. These dikes occur throughout the district, and in certain areas cover approximately half the surface. The youngest consolidated rocks in the district are basalts. These originated outside this belt and entered it through a depression north of Golden Horn. They flowed down the valley of Hoodoo creek to Lewes river, and continued down the river valley to Whitehorse rapids. The basalts were followed by the deposits of the glacial period, consisting mainly of boulder clays and silts, vast quantities of which floor the old valley of Lewes river in the vicinity of Whitehorse. Recent superficial deposits constitute a thin covering overlying the older formations in most places.

The copper belt, as determined by recent discoveries, extends along the valley of Lewes river, from a point east of Dugdale on the White Pass and Yukon railway, northwestward to the base of Mount Haeckel, a distance of about 12 miles (19·2 km.) The width of the belt seldom exceeds a mile (1·6 km.), and in places is confined to a single line. The distribution of the discoveries along the belt is exceedingly irregular. The ore deposits are considered to be of contact-metamorphic origin, and their outcrops dominantly follow a series of limestone areas enclosed in granite, but in places occur between granite and andesite. Where the limestone is absent the belt is practically barren; and considerable stretches of it

otherwise favourable, are deeply buried beneath heavy accumulations of drift.

The principal ore bodies, now being developed, occur in limestone, close to or adjoining the granite. Numerous discoveries have also been made in the granite, often at considerable distances from the limestones. The limited amount of work done on these has so far, however, not disclosed ore bodies of commercial value. The constituent minerals and general character of the ore bodies in the two formations, are very similar. Copper minerals seldom occur in the andesites, but are not altogether unknown there.

The principal economic minerals of the district are bornite and chalcopyrite. Tetrahedrite, chalcocite, malachite, azurite, cuprite, malaconite, chrysocolla, and native copper also occur. The oxides are conspicuous in all the workings, but except at the Pueblo, are seldom important as ores. The iron sulphides are not abundant and nowhere form large masses. The iron oxides, magnetite and hematite, on the other hand are widely distributed, and both occur in large masses. Other metallic minerals of less frequent occurrence are arsenopyrite, stibnite, galena, sphalerite, and molybdenite. Gold and silver occur in all the ores, the values ranging from traces up to several dollars per ton. Gold is ocasionally found native. The principal non-metallic minerals accompanying the ores are andradite, augite, tremolite, actinolite, epidote, calcite, clinochlore, serpentine, and quartz. Of these, andradite, augite, calcite and tremolite are the most abundant. Quartz is sparingly distributed and seldom occurs in quantity.

The ore bodies fall into two classes:—those in which the copper minerals are associated with magnetite and hematite; and those in which the various silicates, principally garnet, augite, and tremolite are the chief gangue minerals.

The magnetite ore bodies are numerous, and occur enclosed completely in altered limestone, along the lime-granite contact, and in a few instances in areas of altered granite. The largest bodies, so far discovered, are: the Best Chance, 360 feet (109 m.) in length; the Arctic Chief, 230 feet (70 m.); and the Little Chief, 100 feet (30 m.) The magnetite masses are always sprinkled, more or less plentifully throughout, with grains and small masses of bornite and chalcopyrite. The copper percentage varies

greatly in different parts of the same deposit, the general average approximating 4 per cent. The gold and silver are negligible in some of the ore bodies and important in others. Besides the copper minerals, serpentine, calcite, clinochlore, and other secondary minerals, as well, rarely, as pyrrhotite and sphalerite, occur associated with the magnetite.

Hematite masses are much less common than those of magnetite. The Pueblo deposit is the only large body known, and is over 300 feet (91 m.) long and 170 feet (52 m.) wide near the centre. This differs from the magnetite ore bodies principally in the greater oxidation of the copper minerals. Some chalcopyrite survives in portions of the deposit, but no bornite in known to have been found.

Deposits characterized by a garnet-augite-tremolite gangue are numerous wherever the lime-granite contact is exposed. They vary from low grade deposits containing only a sprinkling of copper minerals to considerable lenses of shipping ore, such as those developed on the Grafter, Copper King, War Eagle, and Valerie. All the important ore bodies of this class, so far discovered, occur in the limestone close to the granite, and are often separated from the granite by a zone of more or less completely replaced limestone. The valuable minerals are similar to those in the iron masses, and consist mainly of bornite and chalcopyrite. At the Valerie, bornite is absent, and the chalcopyrite is associated with mispickel, the only known occurrence of this mineral in the camp. The siliceous ores contain, as a rule, a higher copper percentage than the iron ores: those shipped up to the present time probably average over 8 per cent. The precious metal contents are moderate, seldom exceeding $3 per ton (·907 tonne).

The development work on the different properties has been practically all performed at or near the surface, little work having been performed at a depth exceeding 100 feet (30m.) With the exception of the Pueblo, the development work other than surface cuts, pits, etc., has been performed by ordinary shafts, tunnels, drifts, etc. On the Pueblo, two shafts have been sunk, but the bulk of the ore has been obtained from the surface by the open-cut or "glory-hole" method, much resembling quarrying. During the summer of 1912, previous to September 1st, over 22,000 tons (19,958 tonnes) of ore had been

mined and shipped from the Pueblo, and it was expected that double this amount would be mined before the winter. During 1912, the Pueblo, Grafter, Best Chance, and Valerie, were being worked most of the summer. About 150 men were employed, of whom 100 to 120 worked at the Pueblo. It is expected that the various properties of the district will be worked somewhat more extensively during the summer of 1913 than in 1912.

During the summer of 1907, Mr. McConnell estimated that probably half a million tons (454,000 tonnes) of ore was in sight, as a result of the development work then performed. [**59**, p. 3]

## Historical.

The history of the Whitehorse copper belt dates back to the early Klondike rush. Discoveries of copper are reported to have been made by miners on their way to Dawson in the summer of 1897. The credit of staking the first claim is due to Jack McIntyre who located the Copper King, July 6, 1898. A number of other claims were located soon after during the same year. In 1900, the first shipment of ore was made from the district, and consisted of 9 tons (8·1 tonnes) of rich bornite ore from the Copper King. This is stated to have yielded 46·40 per cent copper. A second shipment of 460 tons (417 tonnes) of high grade ore was made in 1903. The rising price of copper in 1906 revived interest in the camp, and a number of the most promising claims were sold or bonded. The slow progress in this camp is somewhat remarkable considering the number of favourable showings it contains, and is possibly largely due to the delay in providing proper transportation facilities.

A spur from the main line of the White Pass and Yukon railway, connecting closely with the principal mining properties, has been recently completed. This should assist greatly in the future development of the camp.

## ANNOTATED GUIDE—Continued.

110 m.
176 km.

**Whitehorse**—Altitude 2,084 ft. (636 m.). —From Whitehorse to Lake Laberge, a distance of about 25 miles (40 km.), Lewes river flows in a general northerly direction through a wide prominent valley. For the first 15 miles

(24 km.) below Whitehorse, the stream has an average current of about 4 miles (6·4 km.) per hour. Below this to the lake, the water is rather slack, and the bed and banks of the river are chiefly clay and sand. Throughout this distance the valley is bordered on the east by a prominent range of white bare hills of Devono-Carboniferous limestone.

123 m.
196 km.
**Takhini River**—About 13 miles (21 km.) below Whitehorse rapids, the Lewes is joined by Takhini river on its left limit. This stream at average low water in summer has a discharge of about 3,600 cubic feet (102 cu. metres) per second or about one-half that of the Lewes above the confluence.

136 m.
218 km.
**Head of Lake Laberge**—Altitude 2,050 ft. (623m.)—The valley of the Lewes at the head of the lake is occupied by low swampy flats and terraces composed, where cut by the river, of fine, in places iron-stained, post-glacial, stratified sands, overlying glacial silts.

Lake Laberge [**13**, p. 15] is irregular in outline, has a north-northwesterly trend, and is 31 miles (50 km.) long and about 2 to 5 miles (3 to 8 km.) wide. This body of water is really only a stretch of Lewes river which has become expanded as a result of damming, and possesses consequently almost no perceptible current. Conspicuous, white, Devono-Carboniferous limestone mountains extend along the eastern side of the lake, and attain elevations of about 2,000 feet (600 m.) above the water at a distance of 2 or 3 miles (3 to 5 km.) from the shore. Toward the lower end of the lake, the limestone hills rise more abruptly from the water's edge, but are there only from 400 to 1,200 feet (120 to 360 m.) high. On the west Lake Laberge is bordered by gently sloping hills which attain heights of 2,000 feet (300 m. ) above the lake some miles inland and are nearly all wooded, presenting quite a contrast to the white treeless hills facing them on the east. The rocks on Richthofen island and all along the western

side of the lake, belong to the Laberge Jura-Cretaceous series, and consist dominantly of conglomerates, sandstones, shales, graywackes, and tuffs. [**13,** pp. 30-35. Also see included map of "Braeburn-Kynocks Coal Area"].

Terraces are quite conspicuous along the lake in places, and occur at various elevations up to 350 feet (100 m.) above the water. These are similar to the terraces noted along Lake Bennett and at other points south of Whitehorse, and have had a similar origin. Corresponding terraces may be seen in many places along Lewes and Yukon rivers between Lake Laberge and Dawson.

The valley walls on both sides of Lake Laberge to near the level of the general upland show evidence of pronounced glacial activity, the rock surfaces in many places, particularly along the eastern side of the lake being so smoothed, polished, and striated that it is difficult to walk over them.

170 m.
272 km.

**Lower Laberge**—A broad prominent depression, the Ogilvie valley, joins Lake Laberge at its extreme northwestern corner, and is evidently the valley through which Lewes river flowed in pre-Pleistocene time. During the glacial period it became so filled with gravels, sands, silts, etc., that after the retreat of the ice the river was forced to find a new outlet. The river at the lower end of the lake now turns to the northeast and breaks through an opening in the hills on that side, and to Hootalinkwa, at the mouth of Teslin river, does not follow any marked valley, but flows through a confined depression among irregular lumpy hills, seldom over 1,000 feet (300 m.) above the river. This stretch of river, which is about 30 miles along (48 km.) and is locally known as Thirtymile river, has a general trend somewhat east of north, is very tortuous, and is characterized by its swift, beautifully clear water,—the lake above acting as a huge settling tank from which the water emerges

almost free from sediment. Thirtymile river has an average current of about 6 miles (9·6 km.) per hour.

The white limestone hills are also conspicuous along this stretch of the river; the other exposed rocks are dominantly sedimentary and basic volcanics of Mesozoic age.

101 m. 322 km. **Hootalinkwa**—Government telegraph operators are stationed at both lower Laberge and Hootalinkwa. The latter is a distributing point for the Livingstone creek placer fields [**52**, pp. 25A-30A: **9**, p. 14] and other points reached by Teslin river.

The valley of the Lewes just above the mouth of the Teslin is more constricted than in most places, which is somewhat remarkable being at the point of confluence of such large rivers. The valley of the Teslin appears to be the upward continuation of the valley of the combined streams below their junction. [**13**, pp. 15-17].

From Hootalinkwa to Big Salmon, the Lewes trends in a general way almost due north and has an average current of about 4·8 miles (7·6 km.) per hour. The hills bordering the valley near Hootalinkwa rise to 1,000 or 1,500 feet (300 and 450 m.) above the river, but gradually decrease in a few miles to 800 or 900 feet (240 to 270 m.), at which elevation they continue to near Semenof hills, through which both river and valley are exceptionally constricted. This range, which is dissected by the Lewes some 5 miles (8 km.) above Big Salmon, is about 5 miles (8 km.) wide, has a general northwesterly trend and consists of rounded, wooded hills rising to heights from 1,500 to 2,000 feet (450 to 600 m.) above the river.

About 15 miles (24 km.) down the river from Hootalinkwa, thick-bedded cherty conglomerates outcrop along the left limit of the river and extend downstream for over 10 miles (16 km.) These rocks belong to the Tantalus conglomerates, an upper, coal-bearing, division

of the Jura-Cretaceous rocks of Yukon. No coal has as yet been discovered in these beds between Hootalinkwa and Big Salmon, possibly because they have not been prospected, as everywhere in Yukon where a complete section of these rocks is known to occur, valuable coal seams have been found in them. In fact the best coals so far found in Yukon occur in these conglomerates. The Jura-Cretaceous rocks and the coals in them are described later under "Tantalus Coal Mine."

On the right limit of the river opposite these conglomerates below Hootalinkwa, the rocks are volcanics, dominantly of andesitic types. The Semenof hills appear to be mainly composed of somewhat basic volcanics probably of Jurassic or Cretaceous age.

236 m.
378 km.

**Big Salmon River**—Below Big Salmon river the Lewes turns to the west, almost at right angles to its previous course, and flows in a northwesterly direction to Tantalus. Between Big Salmon to Little Salmon river, the valley is for 8 or 10 miles (13 or 16 km.) more than usually constricted, but just below Little Salmon, the Lewes comes into a wide basin extending several miles from the river on its left limit. Both Big Salmon and Little Salmon rivers, for several miles from the Lewes, occupy broad flat depressions. Splendid exposures and sections of silts occur along this portion of the river. The rock exposures between Big Salmon and Little Salmon consist dominantly of Mesozoic andesites, basalts and related rock types—tufaceous members being prominent at some points.

271 m.
434 km.

**Little Salmon River**—An Indian village and trader's post is stationed at the mouth of Little Salmon river, which possess considerable interest for strangers in this district. Steamers frequently stop here to take on wood for fuel, allowing passengers a half hour or so to go ashore.

From Little Salmon river to Tantalus, the Lewes is extremely tortuous and has an average current of about 4 miles (6·4 km.) per hour. The hills on the right bank of the Lewes in the vicinity of Little Salmon are open, high, and bare, and attain heights from 1,000 to 1,500 feet (300 to 450 m.) above the river in the vicinity. Terraces occur along considerable stretches of the river, at various elevations up to 200 feet (60 m.) above the water.

The rocks outcropping along the right limit of the river below Little Salmon to Eagles Nest, 9 miles (14 km.) distant, are all Jura-Cretaceous sediments of the Laberge series and consist dominantly of conglomerates, sandstones, graywackes, and shales. At Eagles Nest, is a small but conspicuous hill of light coloured Devono-Carboniferous limestone, which can be distinctly seen underlying the Laberge beds. From Eagles Nest to Tantalus the Jura-Cretaceous rocks are exposed continuously along the right limit of the river, and as the dips are low and the strike of the beds about parallel with the general trend of the river for a considerable distance, the same conspicuous reddish sandstones and conglomerates extend along the river for several miles at about the same elevation above the water.

The limestone beds at Eagles Nest extend across the river and are extensively developed to the south. On the left limit of the river below Eagles Nest a somewhat prominent ridge trends in a northwesterly direction and reaches the river about 17 miles (27 km.) below Little Salmon. The rocks composing the ridge are dominantly basic volcanics, and closely resemble those of the Semenof ridge near the river. From below the point where these beds outcrop on the river to Tantalus, the rock exposures are all Jura-Cretaceous sediments.

In pre-Pleistocene time, Lewes river as above mentioned, instead of following the course of the present Thirtymile river below Lake Laberge, swung to the west through Ogilvie valley and continued northward through a broad

depression at present occupied by a chain of lakes, joining its present valley again in the flat across the river from and a short distance below Eagles Nest.

314 m.
502 km.
**Tantalus Butte**—is situated on the right limit of the Lewes about 2 miles (3·2 km.) above Tantalus. Several seams of good coal have been discovered on this hill, three of which are 8 feet 10 in. (2·6 m.); 9 feet 10 in. (2·9 m.); and 7 feet (2·1 m.) thick respectively. These seams have not been developed other than by a limited amount of surface prospect work including a few trenches, open-cuts, etc. [**13**, pp. 52-53; **19**.]

Average outcrop samples of the 8 feet 10 in.; the 9 feet 10 in.; and the best 6 feet of the 7 feet seam, numbered respectively A, B, and C, were assayed by the Mines Branch, Department of Mines, Ottawa, and gave the following results:—

316 m.
505 km.
**Tantalus Coal Mine**—Altitude 1,718 feet (522 m.)

| | A. | B. | C. |
|---|---|---|---|
| Water | 13·64 | 16·32 | 12·87 |
| Volatile combustible matter | 31·83 | 31·72 | 31·72 |
| Fixed carbon | 51·84 | 42·13 | 49 51 |
| Ash | 2·69 | 9·83 | 5·90 |
| | 100·00 | 100·00 | 100·00 |
| Ratio of volatile combustible matter to fixed carbon | 1·63 | 1·33 | 1·56 |
| Potash reaction | Dark. | Brownish. | Red. |
| Colour of ash | Pale reddish brown | Pale brownish yellow. | Yellowish brown. |
| Kind of fuel | Lignite. | Lignite. | Lignite. |

## TANTALUS COAL MINE.

### General Description.

The Jura-Cretaceous beds in Tantalus Coal Area [**13**, pp. 51-53; **19**; **61**, Vol. I, p. 117-118] have an aggregate thickness of about 4,800 feet (1,460 m.) and, mainly for economic reasons, have been divided into the Laberge series and the Tantalus conglomerates. [**13**, pp. 30-38, also see included map of "Tantalus Coal Area"]. The Laberge series consists mainly of conglomerates, sandstones, graywackes, and shales. The overlying Tantalus conglomerates have a maximum observed thickness in the district of about 1,000 feet (300 m.) and consist dominantly of thickly-bedded cherty conglomerates.

All the best coals of Yukon occur in these Jura-Cretaceous rocks, and are found at two distinct horizons, the upper horizon being in and near the top of the Tantalus conglomerates, and the lower horizon being in the Laberge series and within 200 to 300 feet (60 to 90 m.) of the overlying Tantalus conglomerates. The coals are dominantly bituminous in character, and some seams yield a fair grade of coke. In different portions of Yukon the Jura-Cretaceous coals range from high grade lignites to anthracites. The best and most valuable seams have so far been found in the upper horizon, to which belong those at Tantalus mine and on Tantalus butte.

### Particular Description.

Tantalus mine is owned by the Five Fingers Coal Company of St. Paul, Minnesota, and is situated on the left limit of Lewes river about 205 miles (328 km.) down the river from Whitehorse.

The coal outcrops in the river banks and is, therefore, well situated for economical working. The cars are hauled out of level entries by mules, and by means of a cable, operated by a small stationary steam engine, are pulled up an incline, at the top of which the coal is dumped into bunkers ready for loading on river boats or scows. Three seams have been opened up, only the lower two of which have been worked to any extent. The seams vary somewhat in thickness, but average about 7 feet 6 in., 6 feet 6 in., and 3 feet of coal in the bottom, middle, and top seams respectively. The lower two seams have, in places,

not more than 4 feet of rock between them, and the middle and top seams are generally about 7 feet apart. The coal is worked by the pillar-and-stall system, from two level entries, which have been driven about 2,000 feet. The beds in the mine workings, dip to the east at angles ranging from 24° to 40°.

A 500 pound sample from each of these seams taken by the writer in 1908 was treated and analysed by the Mines Branch,—the following being part of the results of this work.*

| | Upper Seam. | | Middle Seam. | | Lower Seam . | |
|---|---|---|---|---|---|---|
| | Raw. | Washed. | Raw. | Washed. | Raw. | Washed. |
| | % | % | % | % | % | % |
| Moisture in sample as received in laboratory.... | 0·9 | ...... | 0·7 | ...... | 0·7 | ...... |
| Proximate analysis of coal dried at 105°C.— | | | | | | |
| Fixed carbon.......... | 58·0 | 59·9 | 54·1 | 60·3 | 56·0 | 59·2 |
| Volatile matter........ | 25·0 | 26·3 | 26·7 | 25·7 | 27·8 | 28·1 |
| Ash.................. | 17·0 | 13·8 | 19·2 | 14·0 | 16·2 | 12·7 |
| Ultimate analysis of dried coal— | | | | | | |
| Carbon............... | 6·98 | ...... | ...... | ...... | 71·1 | ...... |
| Hydrogen............. | 4·0 | ...... | ...... | ...... | 4·3 | ...... |
| Sulphur............... | 0·5 | 0·5 | 0·5 | 0·4 | 0·5 | 0·5 |
| Nitrogen.............. | 0·8 | 0·8 | 0·9 | 0·8 | 0·7 | 0·8 |
| Oxygen............... | 7·9 | ...... | ...... | ...... | 7·2 | ...... |
| Ash.................. | 17·0 | ...... | ...... | ...... | 16·2 | ...... |
| Calorific value of dried coal in calories per gramme | 6,700 | 7,110 | 6,310 | 7,070 | 6,790 | 7,210 |

The number of tons of coal produced from this property during the past few years is approximately as follows:—

| | | | | | | |
|---|---|---|---|---|---|---|
| Year—1906. | 1907. | 1908. | 1909. | 1910. | 1911. | 1912. |
| Tons—5,170 | 8,500 | 4,500 | 3,500 | 3,000 | 3,500 | 3,000 |

*For the complete results of the tests made of these fuels see the following reports:—
13, Appendix III, pp. 59-63.
61, Vol. I, Table XLIV, Vol. II, Table LXX.

ANNOTATED GUIDE (Continued).

316 m. 505 km. **Tantalus Coal Mine**—Altitude 1,718 feet (522 m.) About two-thirds of a mile (1 km.) below Tantalus mine, and on the same side of the river, is a general store and a dismantled R.N.W.M. Police barracks. One-third of a mile (·5 km.) farther along the river bank is situated Carmack's road house which is on the Whitehorse-Dawson waggon-road, 131 miles (210 km.) from Whitehorse, measured along the road. About one-third of a mile (5 km.) below Carmack, Nordenskiöld river joins the Lewes on its left limit.

Lewes river below Tantalus and particularly to Five Fingers rapids, continues to be extremely tortuous, and 6 miles (9·6 km.) below Tantalus swings to the foot of Tantalus butte within half a mile (·8 km.) of a point where it had touched the base of this hill, 8 miles (12·0 km.) farther upstream. The higher hills in this vicinity rise to elevations between 3,000 and 3,500 feet (900 to 1,000 m.) above sea-level.

From Tantalus to Five Fingers coal mine, a distance by river of 16 miles (26 km.) or 8 miles (13 km.) as the crow flies, the rocks along the left limit of the river are mainly Tertiary basalts, similar to those at Miles canyon, in the vicinity of Selkirk, and elsewhere in Yukon. On the right limit of the river these rocks are also extensively developed, but the Jura-Cretaceous rocks are also exposed for about 4 miles (6 km.) above Five Fingers mine. The layer of light grey or nearly white volcanic ash, which is noticeable from Caribou northward, is particularly prominent between Tantalus and Five Fingers, where it is about a foot (·3 m.) thick, and as elsewhere is very near the surface, the vegetation being rooted in it.

332 m. 531 km. **Five Fingers Coal Mine**—The Five Fingers mine [**13**, pp. 53-55; **19**] is situated on the right bank of the Lewes, and the workings are all close to the water's edge. The coal measures on this property belong to the lower

of the two main coal horizons of Jura - Cretaceous age, i.e. they occur near the top of the Laberge series and are consequently several hundred feet below the measures at Tantalus and Tantalus butte.

Some years ago, a slope was sunk about 350 feet (106 m.) on the best seam so far found in these measures, and a number of rooms were driven off this entry. The seam dips to the east at an angle of 16°, and in the lower rooms, is 3½ to 4 feet (1·0 to 1·2 m.) thick. A considerable amount of coal was mined and sold, chiefly in Dawson, but the workings have now been closed for several years.

The top of this old slope is situated in the steep clay and sand bank of the river, and is therefore unstable; consequently when work was resumed under new management in 1906, the entrance was shifted to safer ground, some distance to the south. The new slope was sunk 783 feet, (238 m.) on a seam which also dips at 16° to the east, and is higher in the measures than the seam in the old workings. This upper seam, through in places not more than 6 inches (·15 m.) thick, shows at the bottom of the slope 22 inches (·55 m.) of good clean coal, and 24 inches (·6 m.) of coal and shale.

During 1907 and 1908, very little work was done on the property. In the former year a 26 ft. (7·9 m.) winze was sunk at a point 450 feet (136 m.) down the new slope, to a coal seam 4 ft. 6 in. (1·3 m.) thick, which is apparently the same seam as that in the old workings. Since 1908 the mine has been closed .

The following samples were taken by the writer:—Sample A is an average of the 22 inches (·55 m.) of good coal in the bottom of the 783 ft. (238 m.) slope; and B an average of the bottom of the 26 ft. (7·9 m.) winze. Assayed by the Mines Branch, Department of Mines,

at Ottawa, these samples gave the following results:—

| Sample. | A. | B. |
|---|---|---|
| Water | 5·95 | 5·29 |
| Volatile combustible matter | 40·46 | 36·14 |
| Fixed carbon | 45·16 | 40·12 |
| Ash | 8·43 | 18·45 |
| | 100·00 | 100·00 |
| Coke per cent | 53·59 | 58·57 |
| Character of coke | Firm, coherent. | ........ |
| Ratio of volatile combustible to fixed carbon | 1 to 1·11 | 1 to 1·11 |
| Colour of ash | Reddish. | Reddish. |
| Kind of fuel | Coal. | Coal. |

From Five Fingers mine to Five Fingers rapids the rocks along the river are mainly the Laberge Jura-Cretaceous sediments, but in places volcanics of Mesozoic or Tertiary age occur.

337 m.
539 km.

**Five Fingers Rapids**—Five Fingers rapids are caused by heavy beds of coarse conglomerate of the Laberge series, which cross the river at that point. At one time, a fall probably existed there, but the barrier has now been cut through at several points, giving the rapids the appearance intended to be conveyed by their name. The massive rock buttresses and the narrow tongues or rushing water between, have a formidable appearance. River steamers, however, go through without much difficulty at most seasons, but when the water is high, upstream boats have to be lined through with a cable attached to the bank above.

343 m.
548 km.

**Rink Rapids**—Rink rapids have more the appearance of a broad stony riffle than a rapid, although, especially in high water, the current

Steamer Whitehorse in the Five Fingers rapids.

is swift, being probably about 8 miles (13 km.) per hour.

From Rink rapids to Selkirk, the Lewes is remarkably straight and follows a general course of about S 50° W, the current averaging about 4½ miles (7 km.) per hour. This stretch of the river, more so than most portions of the stream above, contains a large number of islands which are somewhat conspicuous in that they characteristically occupy positions in midstream. The valley is generally wide, and the hills bounding it seldom exceed 1,000 feet (300m.) in elevation above the river. Terraces are prominent, and in most places are from 100 to 200 feet (30 to 60 m.) above the stream.

An exposure of boulder clay occurs a short distance below Rink rapids, and is the most northerly occurrence of this material noted on the Lewes. This point is probably near the limit of glaciation in the Lewes River valley. Glacial striæ several hundred feet above the river were noted along Nordenskiöld river near Carmack, but are not known to have been seen farther down the Lewes.

Rock exposures are infrequent along the portion of the river between Rink rapids and Selkirk. In a few places the slopes of the hills run down to the waters' edge, and it is generally only at such points that rock outcrops occur. Jura-Cretaceous sediments, however, appear to continue downstream on the right limit of the river to below Yukon Crossing.

347 m. **Yukon Crossing**—Altitude 1,597 ft. (485m.)
555 km. Yukon Crossing is the point where the Whitehorse-Dawson wagon road crosses Lewes river, and is 144 miles (230 km.) from Whitehorse, measured along the road. During the winter months, stages carrying passengers and mail, make regular trips between Whitehorse and Dawson, crossing the river at Yukon Crossing on the ice. During the season of open navigation on the river, this road is little travelled, and the river is crossed at Yukon Crossing by means of a ferry.

The hills immediately behind the road-house at Yukon Crossing, consist of dark greenish andesitic rocks which appear to be somewhat extensively developed in that locality. Below Yukon Crossing, 5 and 6 miles respectively (8 and 9·6 km.), Merritt and Williams creeks join the Lewes on its left limit. Up these creeks and within a distance of 3 miles (4·8 km.) from the river, a number of copper claims have been located and have been more or less developed [**12**]. The rocks throughout the Williams and Merritt Creeks area, and for several miles at least down the Lewes, are mainly much altered, dark green, sheared eruptives and granitic rocks. The older sheared members have a pronounced schistose structure and belong to the older pre-Ordovician rocks. These have been here so extensively invaded by the granitic intrusives, that the two appear to be about equally extensive in this vicinity.

Hoo-che-koo bluff [**28**, p. 144B-146B], which is situated on the right limit of the river about 11 miles (17·5 km.) below Yukon Crossing, and which is the abrupt face of an isolated hill against which the river washes, consists of a grey, slightly porphyritic, felspathic rock which is interbedded with fine grained, nearly black argillite. These rocks are much fractured and distorted, and probably are of lower Paleozoic age.

Below Hoo-che-koo bluff for about 25 miles, (40 km.) the few rock exposures along the river consist mainly of diabase or diorite and diabase agglomerates. About 10 miles (16km.) above Selkirk some greyish granite outcrops, which in places contains large porpyhritic feldspar crystals. This granite is similar to that in the vicinity of Williams and Merritt creeks, and is probably related to the Coast Range granitic intrusives.

Commencing about 6 miles above Selkirk, the Tertiary basalts are again developed, and from there extend downstream for over 30 miles (48 km.) Several superimposed flat-lying flows occur, giving rise to a wide basalt plateau.

Bituminous coal of good quality has recently been discovered about 5 miles (8 km.) above Selkirk in the bank on the left limit of the Lewes river in rocks apparently of Jura-Cretaceous age, underlying the basalt flows. As no development work has yet been performed, the number and thickness of the coal seams have not yet been determined.

393 m. 628 km. **Selkirk**—Altitude 1,555 feet (472 m.) Selkirk is the site of an old fort, and is now a trading post and Indian village. It is situated on the left limit of Yukon river just below the confluence of Lewes and Pelly rivers.

Yukon river from Selkirk to Dawson is liberally strewn with islands, and to White river has a current of about 5 miles (8 km.) per hour. The valley throughout this distance is from 800 to 1,000 feet (240 to 300 m.) or more in depth, and has a trend slightly north of west.

For about 25 miles below Selkirk the basalt plateau continues on the right limit of the river, the vesicular lavas overlying older schistose rocks which continue downstream to Dawson. On the left limit of the river these older rocks extend from Selkirk to Dawson. Except for the lavas, the predominant rock between Selkirk and White river consists of a hard, granular, well foliated mica-gneiss. Hornblendic, micaceous, and chloritic schists are also well represented.

491 m. 785 km. **White River**—White river is a turbid stream carrying sufficient sediment to change the colour of the whole Yukon below the confluence. White river joins the Yukon on its left limit, and 10 miles (16 km.) below its mouth.

501 m. 801 km. **Stewart River**—Stewart river enters from the right. From Stewart river to Dawson the valley of the Yukon "is cut through an elevated undulating plateau, on which rest numerous low ranges of rounded and partly bare hills,

Typical scene on Yukon river near Selwyn.

but is not crossed by any well defined mountain range. It is somewhat uniform in appearance, but affords many picturesque and even grand views. Bluffs of rock of a more or less precipitous nature, are of constant occurrence, and bold rampart-like ranges of interrupted cliffs, separated and continued upward by steep grassy or wooded slopes, characterize the banks for long reaches. The flats are few and unimportant, and as a rule the river washes the base of the banks on both sides. The width of the valley varies from one to three miles (1·6 to 4·8 km.), and its depth from five to fifteen hundred feet (150 to 450 m.). Its great size, taken in connection with the hard character of the crystalline rocks through which it has excavated, afford evidence of great age, and point to an origin long antecedent to the glacial period." [**50,** p. 141 D.]

Sections of the rock formations are numerous along the valley, but the geology is intricate and difficult. The predominant rocks are schistose and gneissoid types and crystalline limestone all of lower Paleozoic age or older, which correspond to McConnell's Nasina series, Klondike series, and Moosehide diabase of Klondike district. [**51,** pp. 10 B-23 B]. In places these older rocks have been invaded by various intrusives mainly granite and diabase.

524 m.
838 km.
**Sixtymile River**—Sixtymile river joins the Yukon from the west about 23 miles (36 km.) below the mouth of the Stewart. About 17 miles (27 km.) below the mouth of Sixtymile, some sandstones and shales, thought to be of early Tertiary (Kenai) age, occur intimately associated with andesitic and rhyolitic volcanics, and outcrop along the left limit of the Yukon for about 7 miles (10 km.). [**51,** p. 24B]. These rocks have a considerable development to the west along Sixtymile river.

571 m.
913 km.
**Dawson**—Altitude 1,049 feet (318 m.) Dawson is the principal town in Yukon and is the seat of the Territorial Government. It is

Dawson.

situated on the right limit of the Yukon at the confluence of Klondike river, and is 334 miles (534 km.) from Whitehorse measured along the waggon road or 460 miles (736 km.) by river.

## KLONDIKE GOLD FIELDS.*

### General Description.

Klondike gold fields are situated in Yukon Territory, on the east side of Yukon river, at the confluence of the Klondike, and at about 64° north latitude. The district comprises approximately 800 sq. miles (2,000 sq. km.) and is bounded in a general way by Yukon river on the west, by Klondike river on the north, by Flat creek, a tributary of the Klondike, and Dominion creek, a tributary of Indian river, on the east , and by Indian river on the south.

Topographically, the area included within the Klondike gold fields, is a typical example of a thoroughly dissected upland, and is situated well within the Yukon Plateau physiographic province. Klondike district is underlain by a complex of rock formations ranging in age through the greater part of the geological scale, and presenting extreme variety in structure and composition. The rocks consist dominantly, however, of various schistose members that have generally been considered to be of lower Paleozoic age, but may be Pre-Cambrian. These have been repeatedly pierced by igneous intrusives at widely separated periods. The older rocks are in places underlain by Tertiary sediments and superficial accumulations.

Economically the district is mainly of importance on account of the rich and extensive deposits of gold-bearing gravels which it contains. Placer gold was first found in the Klondike in 1894, and since 1896 this district has been one of the greatest and most widely known placer gold camps in the world. At present the bulk of the placer properties are worked by companies who have spent millions of dollars in equipment and installation, and are obtaining the gold mainly by dredging and hydraulicking. In a few places, however, individual miners still work their

*The general description here given of the Klondike Gold Fields, is to a considerable extent summarized from Mr. McConnell's reports on the district. (51. 58,) The parts, however, dealing with the recent developments, methods of working, equipment, installations, etc., are the result of personal investigations by the writer.


A typical scene on the Dawson wharf during the summer season.

own claims and employ the somewhat primitive old-time methods that were so common a few years ago.

The streams flowing through the area are all gold-bearing to some extent, but only a limited number have proved remunerative. The most productive streams are: Bonanza creek with its famous tributary, Eldorado creek; Bear creek and Hunker creek, flowing into the Klondike; and Quartz creek, and Dominion creek, with Gold Run and Sulphur creeks, tributaries of Dominion creek, flowing into Indian river.

A considerable number of quartz properties are held in different parts of Klondike district and some have been more or less developed. None of them can as yet be considered to have passed the prospect stage.

## TOPOGRAPHY.

Topographically, Klondike district is a typical example of a thoroughly dissected upland. It forms part of the Yukon plateau, which is thought to have been originally part of a great peneplain, at one period of its history elevated so as to constitute a high plateau and subsequently deeply trenched by the various streams by which it is drained. In the Klondike, at least, a second uplift has occurred in comparatively recent times, resulting in a further deepening of the valleys 300 feet to 700 feet (150 to 210 km.). Portions of the old valley bottoms, still covered with heavy accumulations of gravel, remain at many points, forming terraces of various widths, bordering the newer valleys.

Viewed from a distance, Klondike district has a hilly or even mountainous aspect, but in reality consists of a series of long branching ridges, the summits of which have been carved irregularly into hill and hollow by unequal denudation. Most of the ridges originate at or near the Dome, the topographic centre of the district, and the highest point in it.

The Dome is situated 19 miles (306 km.) southeast of Dawson, and about midway between Indian and Klondike rivers. It has a height of about 4250 feet (1295 m.) above the sea, 3050 feet (930 m.) above Yukon river at Dawson, and about 500 feet (152 m.) above the ridges at its base. It is not conspicuously higher than the other hills in the neighbourhood, and the gradual decrease in height out-

A steamer with barge attached starting down river from Dawson.

wards along the ridges radiating from it, is scarcely noticeable to the eye. The Dome is the principal drainage centre of the district. From it, Allgold and Dominion creeks flow eastward, Quartz and Sulphur creeks southward, and Goldbottom and Hunker northward. The ridges separating these streams, although deeply and repeatedly gashed by tributary valleys, are unbroken, and it is possible, starting from the Dome, to reach any part of the district without descending into the valleys. Subordinate drainage centres occur at other places.

## General Geology.

Klondike district is underlain by a complex of rock formations ranging in age through the greater part of the geological scale and presenting extreme variety in structure and composition. The region has been repeatedly broken through by igneous intrusions at widely separated periods, and has been subjected to enormous pressure from earth movements. Alterations in the character of the rocks, induced by dynamic and associated metamorphic agencies, have proceeded to an extreme degree. Massive igneous rocks have been sheared and crushed into finely foliated schists, and the clastics in many places recrystalized to the semblance of igneous rocks. The oldest and most important formations consist of ancient schists, partly of clastic and partly of igneous origin.

The southern part of the district is underlaid by altered sedimentary rocks, now represented dominantly by quartz-mica-schists and crystalline limestones. These are bordered on the north by a wide band of light-coloured, in places almost white, sericite-schists alternating occasionally with greenish chloritic schists. All these various types of schists have been derived from igneous, and largely from massive igneous rocks. The principal producing creeks of Klondike district occur in the area occupied by them. The sericite-schists and associated rocks are replaced near the mouth of Klondike river by green diabase rocks, which are usually schistose in structure, but in places might almost be termed massive. These diabase rocks are everywhere greatly altered and, on Moosehide mountain pass into serpentine. East of the diabase and serpentine area on Moosehide mountain, the sericite-schists alternate on the north with bands of dark quartz-mica-schists, very similar to those bordering them on the north.

The old schist floor of the district is penetrated at numerous points by intrusives belonging to several groups. A massive, coarse-grained, grayish granite resembling the Coast Range granites, cuts the sedimentary schists in Yukon river below Indian river. Serpentine, derived in part, at least, from peridotites, occurs at several points on the crest of the ridge separating Hunker creek from the Klondike, and numerous small, usually oblong areas of comparatively recent rhyolites and andesites are scattered irregularly throughout the district. Massive diabases occur on Indian river below New Zealand creek, and in dykes in the Yukon valley opposite Indian river, and on Eldorado creek. Unaltered sedimentary rocks consisting of clays, shales, sands, sandstones, tuffs and conglomerates nearly destitute of determinable fossils, but probably of Tertiary age, overlie the schists in the lower part of the valley of Last Chance creek, and in separate depressions at several points around the outskirts of the district. These recent sedimentary rocks are associated in every area with dykes, stocks, and sheets of andesite, and in places, with dykes and small areas of diabase.

As Klondike district has not been overridden by ice, the surface rocks, as is usual in unglaciated regions, are deeply weathered. A thick covering of decomposed schist, usually intermingled with the slide rock, mantles the sidehills nearly everywhere. On the ridges the covering is less, and the schists, often worn into fantastic shapes, in places project above the general surface, or are exposed along the sides of the steeper hills.

The surface materials are also permanently frozen. The thickness of the frozen stratum varies considerably, and is less on the ridges than in the valleys, and less also on southern than on northern exposures. A shaft on the ridge south of Eldorado creek reached unfrozen ground at 60 feet (18·2 m.), while one in the valley of Eldorado creek was stopped by running water at a depth of over 200 feet (61 m.) Another shaft, sunk through gravel on the plateau between Bonanza and Klondike river, passed through the frost line at a depth of 175 feet (53·3 m.). The summer heat has little effect on the frozen layer, except in the few places where the surface is unprotected by moss. Exposed gravel beds in favourable positions thaw out to a depth of 4 to 10 feet (1·2 to 3·0 m.), but where moss is present, frost is always encountered close to the surface.

A section across the valley of any of the gold-bearing streams entering the Klondike shows a comparatively narrow, trough-like depression below, 150 to 300 feet deep (45 to 90 m.), bordered on one or both sides by wide benches beyond which the surface rises in easy, fairly regular slopes up to the crests of the intervening ridges. The benches represent fragments of older valley bottoms partly destroyed by the excavation of the present valleys. Narrow rock-cut terraces occur at intervals between the level of the old valley-bottoms and the present level. Auriferous gravels occur on the present valley-bottoms, on the portions of the old valley-bottoms still remaining, and on the rock terraces cut into the slopes connecting them. These deposits may be classified as follows.—

| | |
|---|---|
| Low level gravels | Gulch gravels<br>Creek gravels<br>River gravels. |
| Gravels at intermediate levels. | Terrace gravels. |
| High level bench gravels | Klondike gravels<br>White Channel gravels. |

The low level creek gravels are the most important gravels in the district, and floor the bottoms of all the valleys to a depth of 4 to 10 feet (1·2—3·0 m.). They rest on a bedrock usually consisting of decomposed and broken schists, and are overlaid by a sheet of black frozen muck ranging in thickness from 2 to 30 feet (·6 to 9 m.) or more. They are local in origin and consist entirely of the schists and other rocks outcropping along the valleys. The schist pebbles are usually flat, round-edged discs measuring from 1 to 2 inches (25 to 50 mm.) in thickness and from 2 to 6 inches (50 to 150 mm.) in length. These pebbles constitute the greater part of the deposits, but are associated with a varying proportion of rounded and subangular quartz pebbles and boulders, and, less frequently, with pebbles derived from the later eruptive rocks of the region. The pebbles are loosely stratified, usually embedded in a matrix of coarse reddish sand, and alternate in places with thin beds of sand and muck. These gravels frequently enclose leaves, roots and other vegetable remains, and the bones of various extinct and also existing types of northern animals, such as mammoth, mastodon, buffalo, bear, musk-ox and mountain sheep.

The gulch gravels occupy the upper portions of the main creek valleys and small tributary valleys, and differ from the creek gravels in being coarser and more angular. A considerable portion of their material consists of almost unworn fragments of schist washed down from the adjacent slopes. They contain the same vegetable and animal remains as the creek gravels.

The only river gravels of the district proven, so far, to contain gold in paying quantities, occur in the wide flats bordering the lower portion of Klondike river below the mouth of Hunker creek. The river gravels consist of quartzite, slate, chert, granite and diabase pebbles, which are harder and more rounded than the creek gravels, as a result of the greater distance travelled.

Rock terraces cut into the steep slopes of the present valleys occur at different points. They were produced during the deepening of the valleys, and are simply remnants of former valley bottoms. They are small, seldom exceeding a few yards or metres in width, and a few hundred yards in length. They are also irregular in distribution, and occur at all elevations up to the bottoms of the old valleys. The terraces are beds of gravel, usually from 6 to 15 feet (1.8 to 3.6 ,m) in thickness, very similar to that in the creek bottoms, but showing somewhat more wear. The terrace gravels, like the creek gravels, are overlaid as a rule, with muck, and at one point on Hunker creek, were found buried beneath a hundred feet of this material

High level gravels are extensively distributed along Bonanza and Hunker creeks and some of their tributaries, and also occur on Eldorado, Bear, Quartz, Ninemile, and Allgold creeks. They consist principally of ancient creek deposits, overlaid near the mouths of some of the valleys by gravels laid down by Klondike river, when it ran at a much higher level than at present, and occupied a somewhat wider valley.

High level river gravels occur at various points along Klondike river, and in most places are found at elevations of 200 to 300 feet (60 to 90 m.) above the valley flats. These gravels differ altogether in character and appearance from the White Channel gravels of the creeks. The pebbles are smaller and more rounded, and consist mainly of slate, diorite and quartzite, derived, like those of the present stream gravels, from the mountains of the Ogilvie range. The Klondike gravels as a rule have only a small gold content, but below the mouth of Bonanza creek, they have

been enriched and in places contain gold in commercial quantities.

The White Channel bench or hill gravels are the oldest in the district, and, excepting the present creek gravels, are the most important from an economic standpoint. They were originally creek gravels, deposited in a similar manner to those at present occupying the low levels, and their elevated position is due to an uplift which affected the whole region bordering the Yukon from Stewart river northwest to the Alaskan boundary and for a considerable distance beyond. This uplift, and a slight depression which preceded it, produced many notable changes in the topography of the country. The White Channel gravels, however, differ somewhat from the ordinary type of stream deposit. They are very compact as a rule, and in some of the hydraulic cuts stand up in almost vertical cliffs, even when the face is unfrozen. The white or light gray coloration from which these gravels derive their name, is very conspicuous in most of the sections, but is not universal, as red, yellow, and dark gray beds frequently occur. The deposit is highly siliceous, the principal constituent consisting of rounded pebbles and rounded and subangular boulders of vein quartz. Flat schist pebbles and boulders, usually in a more or less advanced stage of decomposition, occur with the quartz, as also do occasional pebbles derived from the various dikes and stocks outcropping along the valleys. The pebbles and boulders seldom exceed 18 inches (.5 m.) in diameter, and are embedded in a compact matrix consisting essentially of small sericite plates and fine angular quartz grains. A few large angular blocks from 3 to 4 feet (.9 to 1.2 m.) in diameter occur in places but are rare and generally near bedrock.

The White Channel gravels are strikingly uniform in composition and general character, and as a rule the bedding planes are inconspicuous. Their range in thickness is from a few feet to 150 feet (1 to 45 m.), and the original width from 200 yards to over a mile (180 m. to over 1.6 km.). Unlike the creek and gulch gravels they appear to be destitute of vegetable and animal remains.

In places the typical compact variety of the white Channel gravels is replaced toward the sides of the old valley by flat rusty coloured gravels, more loosely bedded and containing a smaller proportion of quartz than the ordinary white variety. These probably represent flood plain deposits and are seldom productive.

The White Channel gravels were probably deposited by winding streams with easy grades and comparatively slack currents. The predominance of vein-quartz pebbles and boulders, the most resistant rock in the district, gives them the character of a residual deposit. They were built up slowly, and in the long process the softer rocks were mostly destroyed and carried away. The age of these deposits has not been determined, but they must have been formed at least as early as the Pliocene.

The gold of the Klondike placer deposits varies greatly in fineness, not only on different creeks but also along different portions of the same creek, due to its being in all cases alloyed with silver in varying proportions. The lowest grade gold in the camp has a value of about $12.50 per ounce, and some of the gold obtained from Upper Hunker creek has exceeded $17.50 per ounce.

The variation in the fineness of the placer gold appears to depend mainly on original differences in the vein gold from which it was derived. Creeks draining certain areas in the district carry low grade gold, while other areas supply high grade. While the fineness of the placer gold is thus supposed to conform n a general way with that of the original vein gold, some changes are evidently produced by the leaching out of a portion of the silver contents

## Placer Mining Operations.

**General.**—In a few localities, as on Quartz creek, along the lower portion of Sulphur creek, and on a few outlying creeks, private parties are working their properties with small outfits, and there, the old-time methods, formerly so extensively employed are still to be seen. Throughout the greater part of the district, however, the placer deposits are owned and operated by large companies or corporations who work their holdings on an extensive scale. The larger companies are the Yukon Gold Company, Boyle's Concession Limited, and a company controlled by Mr. A. N. C. Treadgold. These companies control the bulk of the placer property in Klondike district, and in attempting to give a general description of the placer mining operations in Klondike district, possibly the best and simplest manner of so doing will be to describe briefly the installation and work of each of these companies.

Shovelling-in on Dominion creek.

In mining in this district many changes were necessarily introduced in adapting to the frozen gravels of Yukon the placer mining methods previously understood and employed in California and other temperate climates. The dredges had to be strongly built in order to withstand the severe service of digging the broken schists which compose the bedrock, and the frozen gravel which is almost as impenetrable as granite. Probably the most serious problem, however, was to overcome the frozen condition so that the material could be handled as readily as similar ground in California or elsewhere. These matters are of intense interest to the mining engineer.

**The Yukon Gold Company.**—The Yukon Gold Company owns practically all the more important gravels on Bonanza, Eldorado and Hunker creeks and their tributaries, the holdings of the company being mainly included in an area about 25 miles (40 km.) in diameter.

The operations of the Yukon Gold Company in Klondike district are, in general, limited to two phases of placer mining, viz., dredging and hydraulicking. The gravels in the valley bottoms are all dredged, but those higher up on the hills and sidehills, which cannot be conveniently reached by the dredges, are hydraulicked, and in general the lower deposits are first worked so as to afford tailings ground when working the higher gravels. During the season of 1912 an average of about 600 men were employed by this company, 400 of whom were engaged in connection with dredging, about 130 on the hydraulic properties and ditches supplying these with water, and the rest were employed mainly in the machine shops, power plant and stables.

The Yukon Gold Company has built and is operating eight dredges, as follows:—

Three Bucyrus 5-foot boats,
One Marion 7-foot boat,
Four Bucyrus 7-foot boats.

The 5-foot and 7-foot boats have buckets with a capacity of 5 and 7 cubic feet respectively (·14 and ·19 cubic metres). All are electrically driven, elevated, close-connected bucket-line dredges of the revolving screen and stacker type. Two of the boats, numbers 8 and 9, which were built during 1911, have hulls constructed entirely of steel.

A dredge in the process of construction.

The dredging season opens about May 1st and the dredges can operate from then until some time between October 15 and November 1, an average of about 175 days each year.

The capacity of the dredges on the creeks in which they are working, has proved to be about 100,000 and 120,000 cubic yards (76,000 and 91,000 cubic metres) per month for the 5-foot and 7-foot boats respectively. The area they cover depends largely on the depth of the ground in which they are working. During 1912, however, the 5-foot boats covered, on an average, about 12,000 square yards (10,000 square metres), and the 7-foot boats an average of about 16,500 square yards (14,000 square metres) per month. The dredges run day and night, and shut down only for repairs or to clean up, the latter being necessary about every 3 to 9 days.

The ground to be dredged is all previously thawed. In some areas, as in the neighborhood of a creek, or where the moss has in some way become stripped off the surface, the ground has become naturally thawed. In places, also, the gravels have been thawed during former mining operations, but the greater part of the ground is thawed by steam just previous to dredging. Long, hollow, perforated steel tubes with sharpened points are driven into the ground, and steam is forced through these and into the surrounding frozen ground.

The dredges take up, in addition to the gravels and overburden, the underlying bed rock to a depth of 3 to 9 feet (·9 tp 2·7 m.).

The properties on which the Yukon Gold Company's dredges were situated near the close of the season of 1912 are as follows, and in all probability these boats will be very close to these positions during 1913:—

No. 1.—5-foot Bucyrus boat, on No. 97 below Discovery on Bonanza creek.*

No. 2.—5-foot Bucyrus boat, on No. 60 below Discovery on Bonanza creek.

Nos. 3 and 6.—5-foot and 7-foot Bucyrus boats, on No. 76 below Discovery on Bonanza creek.

No. 4.—7-foot Marion boat, on the Anderson Concession on Hunker creek.

No. 5.—7-foot Bucyrus boat, on No. 17 below Discovery on Bonanza creek.

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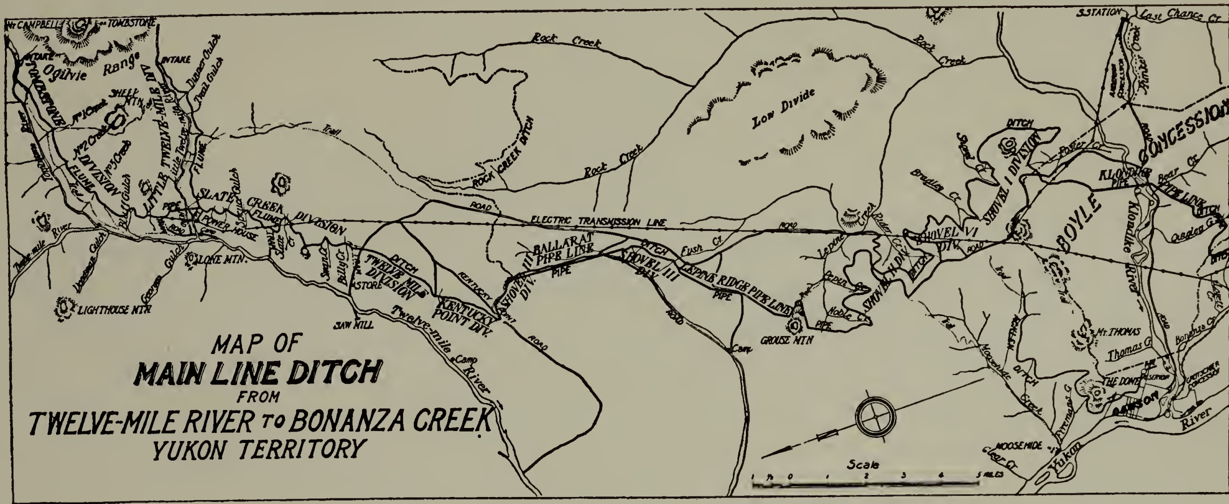
*For these positions, see map accompanying R. G. McConnell's report 58.


MAP OF
MAIN LINE DITCH
FROM
TWELVE-MILE RIVER TO BONANZA CREEK
YUKON TERRITORY
Ogilvie Range
TOMBSTONE
INTAKE
LITTLE TWELVE-MILE DIV.
SLATE CREEK DIVISION
POWER HOUSE
LONE MTN.
LIGHTHOUSE MTN
Rock Creek
ROCK CREEK DITCH
Low Divide
ELECTRIC TRANSMISSION LINE
ROAD
BALLARAT PIPE LINE
SHOVEL III DIV.
LEPINE RIDGE PIPE LINE
KENTUCKY POINT DIV.
TWELVE MILE DIVISION
SAW MILL
Twelve-mile River
GROUSE MTN
SHOVEL VI DIV.
SHOVEL I DIVISION
BOYLE
CONCESSION
Klondike River
MT. THOMAS
THE DOME
DAWSON
MOOSEHIDE
Yukon River
Scale
Last Chance Cr

No. 8.—7-foot Bucyrus boat with steel hull, on No. 10 above Discovery on Upper Bonanza.

No. 9.—Sister boat of No. 8, on No. 10 Eldorado creek.

In connection with the hydraulic operations of the Yukon Gold Company, one of the greatest problems originally confronting them, was that of obtaining sufficient water to work their properties. To obtain this water a giant ditch system has been constructed and a storage dam built.

The storage dam, situated on Upper Bonanza creek, is 68 feet (20 m.) high at the crest, 205 ft. (62 m.) wide at the base, and 465 feet (141 m.) long at the top, with an impounding capacity of 54,000,000 gallons (245,000,000 litres).

The main ditch conveys water from Little Twelvemile river to the creeks of the Klondike district. The main ditch system consists of 64·2 miles (102·7 km.) of main line, composed of 15 miles (24 km.) of flume, 37 miles (59 kn.) of ditch, and 12 miles (19 km.) of pipe line, crossing five depressions and delivering water to the Lower Bonanza hills under a head of 500 feet (152 m.). The capacity of the main ditch is 5,000 miner's inches. The Bonanza Extension is approximately 6 miles (9·5 km.) in length, has a capacity of 3,000 miner's inches and crosses three depressions. The total length of the ditch system and extensions is 75·2 miles (115·5 km.).

Practically the entire construction work of the Yukon Gold Company, including the ditch system, was completed in three seasons of four months each, or a little over one year of actual construction work. Considering the unusual difficulties to be overcome, this work may be justly called an engineering triumph. The Klondike syphon—the huge pipe line which carries the water across the valley of the Klondike—was itself an undertaking of considerable magnitude. Mr. T. A. Rickard in his description of this ditch system writes [**64**]: "The country traversed by this ditch is a rolling woodland indented by the alluvial flats of the Klondike, the Twelvemile, and other streams flowing into the Yukon river. As seen from a height, the wilderness stretches unbroken from the meandering shimmer of the Klondike, enclosed within high banks on which white scars mark bench-diggings, to the Ogilvie range, where, far to the north, the snow still lingers in token of the gift of water that shall enable man to win the gold from the deposits of gravel strewing the tortuous valleys."

Hydraulicing on Lovitt gulch.

In preparing to build the ditch, the first step was to place a sawmill on Twelvemile river, and thus to obtain the lumber for construction. Then an electric generating plant was erected and the wires were strung on poles for 36 miles (57 km.), transmitting power from Little Twelvemile river to Bonanza creek. While this was being done, surveys for the ditch were hastened; and as soon as these were completed, the right-of-way was cleared. The small growth of forest was removed, and the moss stripped from the frozen ground for a width of 22 yards (19 m.) Steam shovels were then put to work, and while they were digging the ditch, the sawmill on the Twelvemile yielded the lumber needed for the construction of the flume and for other purposes. Seven million feet (board measure) of lumber were cut; this depleted the small forest in the vicinity, but it proved sufficient.

In connection with building the ditch, "roads of the corduroy type have been constructed, moss being laid on the poles and dirt on the moss. The trails traverse the brush in straight lines. Horses and men, steam and muscle, have fought against the wilderness and subdued it. The big ditch looks like a Panama canal, and the steam-shovels gnawing and digging in the deep cuts recall pictures of Culebra. Many of the labourers had worked on the Isthmian canal, and assuredly the young engineers were as proud of the work they were accomplishing as if it were a national or even an international enterprise." [**64**].

About 14 hydraulic properties were operated in 1912 on the different hills and gulches along Bonanza and Hunker creeks, the majority of these being on Bonanza creek below Grand Forks. These hydraulic properties are equipped with auxiliary pipe lines from the main water system, gates, tunnels, cuts, sluiceways, and giants from which the streams of water are driven with a pressure of upward of 100 pounds to the inch (7 kilogrammes to the square centimetre) and strike the banks with a roar that can be heard for miles.

The company's hydro-electric power plant is operated by water from Little Twelvemile river carried through 5 miles (8 km.) of flume and delivered to the plant under 650 feet (197 m.) net effective head. The installation consists of three 650 K.W. generators, direct connected to three water wheels of the impulse type. The main transmission here is 36 miles (57 km.) in length, operating

Hydraulicing on American hill

at 35,000 volts with 18·2 miles (29·1 km.) of extensions and secondaries.

**Boyle Concession Ltd.**—The Boyle Concession Ltd., has taken over the holdings of the Canadian Klondike Mining Company; controls and operates the properties of the Bonanza Basin Gold Dredging Co.; and operates the plant of the Granville Power Company.

The holdings of the Boyle Concession Ltd. include the Boyle Concession, about 4 miles (6·4 km.) of the creek bed of Allgold creek, and 4 miles (6·4 kn.) of the creek bottom of Flat creek. The Boyle Concession comprises 6·7 miles (10·7 km.) of the valley of Klondike river to the summits on either side, also Bear creek and its hillsides, and the Klondike River slope of Lovitt hill; in all about 40 square miles (103 sq. km.). The holdings of the Bonanza Basin Gold Dredging Co. include about 50 placer claims in a group at the lower end of Klondike River valley and just below the Boyle Concession; nearly all Last Chance creek with adjoining hillsides; part of Dago hill; a number of placer claims on the upper end of Hunker creek; and some placer claims on Upper Eldorado.

The operations of the Boyle Concession Ltd., are confined at present to dredging. Two dredges were in operation in 1912, and two more were being built.

No. 1 dredge is an electrically driven boat, with a close-connected bucket-line of 68 buckets, each having a capacity of $7\frac{1}{2}$ cu. ft. (·21 cu. m.). This dredge has a total motor capacity of 350 horsepower and has been operating continuously each season since 1905. No. 2 dredge is an electrically driven boat with close-connected bucket-line of 68 buckets, each having a capacity of 16·1 cu. ft. (·45 cu. m.). This dredge has a total motor capacity of 1005 horsepower, and started operating in 1910 and has since operated continuously during the dredging seasons.

These two dredges are both operating in the valley of the Klondike on the Boyle Concession.

The two dredges being erected will be very similar to No. 2, but will have slightly larger hulls and will be equipped with some new features for protection in operating during severe weather. Each boat contains over 1,000 tons (907 tonnes) of machinery and required 612,000 feet of lumber in the building. These are being erected on the property of the Bonanza Basin Gold Dredging Co., below the Boyle Concession.

Dredge No. 2, belonging to the Boyle Concession Limited, operating on the Boyle Concession in the Klondike valley.

The Boyle Concession Ltd. has a machine shop capable of making all repairs at the mouth of Bear creek, and also owns three 35-ton steam shovels with hauling equipment, and other machinery.

The Granville Power Company has a 10,000 horsepower hydro-electric power plant situated in the valley of Klondike river near the mouth of the North fork. The water is taken from the North fork of Klondike river through 6 miles (9·5 km.) of ditch having a capacity of 15,000 to 20,000 miner's inches, and is supplied to two turbines through two pipes with an effective head of 228 feet. (69 m.).

The power plant consists of two units, and includes two I. P. Morris 5,000 horsepower wheels of the reactionary type, two alternating current generators and two excitors built by the Westinghouse Electric Manufacturing Co. The power is generated at 2,200 volts and stepped up at plant to 33,000 volts and is carried over two main distributing lines, one down Klondike river to its mouth, and the other across the divide to the Indian River watershed.

This plant ran until December 21st, 1911, and the company hopes to be able to instal devices enabling them to operate throughout the entire winter.

**Treadgold Property.**—A company managed by Mr. A. N. C. Treadgold holds extensive interests mainly on the Indian river side of the divide. This company controls practically all Dominion creek; has interests on Sulphur creek; controls most of Quartz creek and Indian river below Quartz creek; and also has a few claims on the upper end of Eldorado creek. During 1912 the operations of this company were mainly confined to Dominion creek, where they did only preliminary work. This consisted mainly in removing the overburden by ground sluicing and so preparing the ground for future development.

Granville Power Company's power house in the valley of the Klondike near the mouth of the North Fork.

## GOLD PRODUCTION.

The placer gold production of the Yukon from 1897 is as follows:—

| Yeor. | |
|---|---|
| 1898 | $10,000,000 |
| 1899 | 16,000,000 |
| 1900 | 22,275,000 |
| 1901 | 18,000,000 |
| 1902 | 14,500,000 |
| 1903 | 12,250,000 |
| 1904 | 10,500,000 |
| 1905 | 7,876,000 |
| 1906 | 5,600,000 |
| 1907 | 3,150,000 |
| 1908 | 3,600,000 |
| 1909 | 3,960,000 |
| 1910 | 4,550,000 |
| 1911 | 4,580,000 |
| 1912 | 5,660,000 |

The figures for 1912 are only approximate. The low production during 1907, 1908, and 1909 was due mainly to the fact that at that period placer mining was undergoing a transition from the old to the new methods. The Yukon Gold Company had acquired most of the ground that had formerly been the most productive, and were devoting their energies to installing their new equipment rather than to mining.

The figures given above are for the entire Yukon Territory, but the gold production from points outside of the Klondike has probably never exceeded $100,000 per year.

## QUARTZ MINING—[**51, 3,** 16].

Considerable interest has of late been evinced in the quartz veins of the Klondike, and special efforts are being made to develop the lode mining of this district, in the hope that a revenue may eventually be derived from this source that will continue to foster the mining industry of this portion of the Yukon when the placer deposits have become exhausted, which it is thought, however, will not be for many years yet to come.

A great amount of quartz occurs in the old schistose rocks that are so extensively developed in Klondike dis-

A property on Hunker creek, being worked by individuals by means of a self-dumping equipment.

tricts, and in some localities it is in sufficient quantity to even constitute a considerable proportion of the whole rock mass. The quartz occurs prevailingly in veins which exhibit considerable variety of form and are as a rule small and non-persistent, but range in size from mere threads to masses several hundred feet in length, but in most p aces less than 10 feet (3 m.) in thickness.

The quartz veins are characteristically but slightly mineralized; pyrite and more rarely magnetite occur in places in sufficient quantity to produce a reddish coloration on the exposed and oxidized portions of the veins, and in a few places the quartz contains particles of galena, chalcopyrite, and native gold.

Often fair, and occasionally even high, assays are ob tained, but, in most cases, it is not known, even approximately, what average amounts of gold the quartz contains. From the various properties that have been examined, however, it is concluded that the gold is always either associated with metallic sulphides, or is at or near the contact between the quartz and schists; in the latter case the gold is found in both vein material and wall rock.

A considerable numbeı of quartz claims have been located in the district. Among the more promising properties now being held, and those on which the most energy has been expended are:—the Lone Star group, near the head of Victoria gulch, a tributary of Bonanza creek; the Violet group, situated along the divide between Eldorado and Ophir creeks; the Mitchell group on the divide between the heads of Hunker and Goldbottom creeks; the Lloyd group and neighbouring claims situated along the divide between the heads of Green gulch and Caribou gulch, tributaries respectively of Sulphur and Dominion creeks; and several groups of claims on Bear creek near where joined by Lindow creek. Of these the only properties on which any development has been performed, other than the necessary assessment work, are the Lone Star and Violet groups.

No work has been performed on the Violet group for several years, but it is claimed that over $60,000 had been spent in developing the property previous to 1910.

On the Lone Star group several hundred feet of work has been performed in the form of open-cuts, trenches, shafts and tunnelling. A four-stamp Jos' ua Hendry mill has also been erected on the property, and a gravity tramway 3500 feet (1064 m.) long has been constructed to convey

the ore from the workings to the mill on the creek 900 feet (270 m.) below. In addition, a power line 4 miles (6.4 km.) long has been built to convey power to the mill from the power line of the Northern Power and Light Company on Bonanza creek.

The total gold production from this property has so far been small, and not nearly enough to pay for the development work. All these properties therefore, however promising their character, have still to be considered as being in the uncertain prospect stage.

## JUNEAU-YAKUTAT SECTION.

BY

LAWRENCE MARTIN.

### INTRODUCTION.

The Juneau-Yakutat section of C 8 excursion includes the steamer journey from Juneau to Yakutat bay and return, and also a stop-over of two or three days at Yakutat bay, and a few hours stop at Glacier bay. Short excursions can be made on foot and by boat while at Yakutat bay to examine interesting points along Malaspina glacier and elsewhere in the vicinity. Between Juneau and Yakutat the coast line with its glaciers can be viewed at close range from the steamer; in addition it is intended to land in Glacier bay for a few hours and examine the front of Muir glacier.

This excursion should prove of interest and value to glacial geologists and physiographers, for possibly in no part of the world can glaciers and glacial activity be as well observed and on so tremendous a scale.

The subject matter of this section is largely new material but a part is condensed or abstracted from reports by the late R. S. Tarr and the author, actual quotations being made in a few places from our published reports in the U. S. Geological Survey professional papers, and our forthcoming book on research work in Alaska for the

National Geographic Society. The author is indebted to Mr. Henry Gannett, chairman of the Research Committee of the National Geographic Society, for permission to reproduce the accompanying copyrighted topographic maps of Hidden glacier, Nunakak glacier and of Turner, Hubbard and Variegated glaciers and some of the photographs which are from the book of our investigations for the Society on the Yakutat and Glacier Bay regions.

## ANNOTATED GUIDE.

0.0 m. 0.0 km. **Juneau**—Leaving Juneau the steamer proceeds westward across the lower end of Lynn canal toward the entrance to Icy strait, but in so doing it follows a somewhat devious course around various points and islands.

70 m. 112 km. **Icy Strait**—The route continues through Icy strait, which has a northwesterly trend. At the junction of this fiord with Lynn canal there is a discordant submarine step, Icy strait hanging above Lynn canal because of superior glacial erosion in the latter. The bottom of Icy strait slopes eastward toward Lynn canal from the Glacier Bay submarine divide, to the west of which the bottom of Cross sound slopes westward to the Pacific ocean.

Something may be seen here of the fish traps for collecting salmon.

105 m. 168 km. **Entrance to Glacier Bay**—Continuing through Icy strait, the entrance to Glacier bay is reached 105 miles (168 km.) from Juneau.

## THE GEOLOGY AND PHYSIOGRAPHY OF GLACIER BAY.

### Rock Formations.

The rocks in the vicinity of Glacier bay are shown by the studies of H. F. Reid, [**62, 63**], H. P. Cushing [**24**], and F. E. and C. W. Wright [**88,** Plate II], to be argillites, slates, and limestones, of Paleozoic (perhaps Carboniferous) age, with diorite and other igneous rocks of Jurassic, Cretaceous, or later age.

## Topography.

Glacier bay is a broadly open fiord between the Fairweather range and the mountains on the western side of Lynn canal. It is about 4 miles (6.4 km.) broad at the mouth, widens to about twice this breadth, and then branches. One arm, Muir inlet, extends due north about

Excursion C 8.


Relief map of Glacier bay and Lynn canal.

15 miles (24 km.) to the ice cliffs of Muir glacier, which surround its head, and the other arm extends northwestward for 35 miles (56 km.) where it is terminated by the Grand Pacific glacier. The latter arm is branching, with six good-sized tributary fiords also terminated by tidal glaciers. The extreme length of the bay from its mouth to the tidal front of Grand Pacific glacier is over 60 miles

(95 km.); the distance from the mouth to the head of Muir inlet is about 38 miles (60 km.).

Except at the very mouth, the entire fiord and its branches are mountain-walled though there are small areas of low-lying land along portions of the shore line. At the mouth of the bay, especially on the eastern side, there is an extensive flat extending eastward for several miles from Pt. Gustavus, and stretching northward to Beardslee islands and the neighboring coast. This low area, including the islands and associated shoals, undoubtedly has been formed by glacial deposition during a former expanded stage of the glaciers of the region. Farther up the bay the mountains rise from 2,000 to 5,000 feet (600 to 1,500 m.) within a mile or two of the fiord, and near the branching head, to elevations of 6,000 to 7,000 feet (1,800 to 2,100 m.). Complete soundings have not yet been made in this fiord, but at the narrowest part of Muir inlet there is a known depth of 618 feet (187 m.), and in the narrowest part of the northwestern arm of Glacier bay, of 720 feet (218 m.). Depths of 300 to 600 feet (90 to 180 m.) have been found in most of the soundings, and there is every reason to believe that the waters of the bay are prevailingly deep. Yet there are numerous rock islands, especially in the broader part of the bay below Muir inlet and the northwestern arm.

This fiord and its branches have a noble setting; not only are the fiord walls steep and lofty, but the background rises still higher into the perpetual snows. In a great semicircular area are lofty, snow-covered peaks and broad expanses of snowfields, from which innumerable glaciers descend toward the inlet and its several branches. The most extensive continuous snowfield is around the head of Muir inlet; but the loftiest and grandest mountains lie to the west and northwest where Fairweather, Grillon, and other peaks of the Fairweather range rear their summits to elevations of 12,000 to 15,330 feet (3,600 to 4,660 m.).

## Present-Day Glaciers.

From these vast, encircling snowfields come scores of valley glaciers which unite finally into a few main ice tongues. There are now twelve tidal glaciers in this inlet, and there are a number of other ice tongues ending on the land, which have recently become independent by recession

of the main glaciers to which they were formerly tributary. One by one the tidal glaciers have been severed by recession, a continuation of which has forced their fronts back toward the inlet heads. From the ends of the non-tidal ice tongues innumerable streams flow down over the land; and from the tidal glacier fronts icebergs are discharged into the sea,



Muir glacier in 1911.

littering the fiord waters with floating ice, which in places seriously interferes with navigation, even with small boats. This is especially true toward the head of the northwestern arm of the bay, but floating ice is found throughout the inlet, and some even escapes from the bay into Icy strait.

Although the topographic conditions in the mountains back from Glacier bay are known only in general, it is possible to divide the glaciers into three groups. The first of these ncludes the Muir glacier and the Carroll and Rendu glaciers to the west; the second, fed mainly from the Fairweather range, includes the Grand Pacific, John Hopkins, Lamplugh, and Reid glaciers; and the third, fed from the mountains between Brady glacier and Glacier bay,

includes the Hugh Miller, Charpentier, Geikie, and Wood glaciers. The excursion will visit only Muir glacier, so the others will not be discussed further.

Muir glacier [**62, 63**] is by far the largest and most important glacier of the region. It is fed from a broad, semi-circular snowfield area, above which rise mountains 5,000 to 7,000 feet (1,560 to 2,700 m.) in height. Other



Muir glacier on 1911. Ice resting on outwash gravels containing logs. Nearly 8 miles north of position of ice front of 1899. The ice here was over 1,200 feet thick in 1892.

glaciers descend northward and eastward from this area to Lynn canal and from the valleys which extend northwestward from its head. Davidson glacier is one of these. A very large number of ice tongues from this snowfield unite in a mountain-enclosed amphitheatre to form the broad ice field of Muir glacier, with mountain peaks and ridges rising above the ice surface. The total drainage area of Muir glacier is about 800 square miles (2,000 sq.km.), with over 350 square miles (900 sq. km.) of glacier surface, the two main tributaries having lengths of 20 and 22 miles (32 and 35 km.).

## Historical Statement of Studies of Muir Glacier.

The first description of the region is that given by Vancouver, of Lieutenant Whidbey's observations in 1794, when the glacier front seems to have been out as far as the Beardslee islands. The region was visited by Lieutenant Wood in 1877 and by John Muir in 1879 and 1880, at which time the glacier since named Muir glacier terminated in Muir inlet. The first geologist to observe and describe it was Lamplugh in 1884; C. F. Wright spent a month studying Muir glacier in 1886 and presented the first fairly full description. I. C. Russell spent a few hours in Muir inlet in 1890, and in 1890 and 1892 H. F.



Stumps of buried forest, Muir inlet, Glacier bay.

Reid made extensive surveys, on the basis of which he has published by far the most comprehensive account of Muir and the other glaciers of Glacier bay [**62, 63**]. In this, for the first time, the other glaciers are described and mapped. H. P. Cushing, who accompanied Reid on the 1890 expedition, has also written upon the region [**24**]. The Canadian Boundary Commission mapped the region

in 1894, and Otto Klotz has written about the glaciers, particularly about the great recession. The Harriman expedition visited the bay in 1899, and G. K. Gilbert [**31**] has discussed the phenomena observed; while Henry Gannett and John Muir have presented briefer accounts. C. L. Andrews [**1**] visited and described Muir glacier in 1903. F. E. and C. W. Wright [**95**] studied and mapped the glaciers in 1906, but have not as yet published their full report. In 1907 the Boundary Survey made a new map of the Glacier Bay region. Fremont Morse [**60**] and Otto Klotz [**38**] have described the condition of the glacier in that year. Tarr and Martin [**77**] made a brief study of Muir glacier in 1911. Thus we have a fairly full record of the conditions at Muir glacier from 1879 to 1911.

## Glacier History similar to that of Yakutat Bay.

The history of Muir glacier and the other ice tongues of Glacier bay is strikingly similar to the glacial history of Yakutat bay. There was (*a*) an ancient period of expansion of the glaciers, followed by (*b*) a great recession during which Muir glacier was even smaller than at present. Then came (*c*) a second period of expansion, followed by (*d*) the modern recession, which is still in progress. This modern recession has not yet been interrupted by such a great series of forward movements as the recent advances of nine glaciers in Yakutat bay, though (1) Muir glacier advanced slightly between 1890 and 1892, (2) Rendu glacier pushed forward about 1½ miles (2·4 km.) between 1907 and 1911, and (3) an unnamed, adjacent, cascading glacier advanced over 1,300 feet (395 m.).

The evidence of the ancient expansion is found in the glaciated topography and the glacial deposits of the fiord. The proof of the ensuing recession comes from the buried forests. There are trunks of mature trees in deposits which rest upon glaciated surfaces, some logs found by Tarr and Martin being as far north as the ice front of 1911. The second expansion is indicated by the youthful vegetation of southern Glacier bay and by the historical observations of Whidbey and Vancouver in 1794.

The stages in the modern recession are summarized in the following table:—

| Year. | Movement. | Amount. | Rate per year. | Based on Observations by |
| --- | --- | --- | --- | --- |
| Before 1794 . | Advance... | 34+miles (54 km.) | .......... | Vancouver and Whidbey. |
| 1794 to 1880. | Retreat.... | 24+miles (38 km.) | 1,488 ft. (452 m.) | Muir. |
| 1880 to 1884. | Retreat.... | .......... | .......... | Lamplugh. |
| 1880 to 1886. | Retreat.... | 4,000 ft. (1,200 m.) | 666 ft. (202 m.) | G. F. Wright. |
| 1886 to 1890. | Retreat.... | 3,300 ft. (1,000 m.) | 825 ft. (250 m.) | Reid. |
| 1890 to 1892. | Advance... | 900 ft. (270 m.) | .......... | Reid. |
| 1892 to 1894. | Retreat.... | .......... | .......... | Boundary Survey. |
| 1892 to 1899. | Retreat.... | 1,900 ft. (570 m.) | 271 ft. (82 m.) | Gilbert & Gannett. |
| *Earthquake* | | | | |
| 1899 to 1903. | Retreat.... | 12,620 ft. (3,830 m.) | 3,155 ft. (959 m.) | Andrews. |
| 1903 to 1906. | Retreat.... | 18,480 ft. (5,610 m.) | 6,160 ft. (1,870 m.) | F. E. & C. W. Wright |
| 1906 to 1907. | Retreat.... | 13,200 ft. (4,000 m(). | 13,200 ft. (4,000 m.) | Morse, Klotz. |
| 1907 to 1911. | Retreat.... | 2,000 ft. (600 m.) | 500 ft. (150 m.) | Tarr and Martin. |

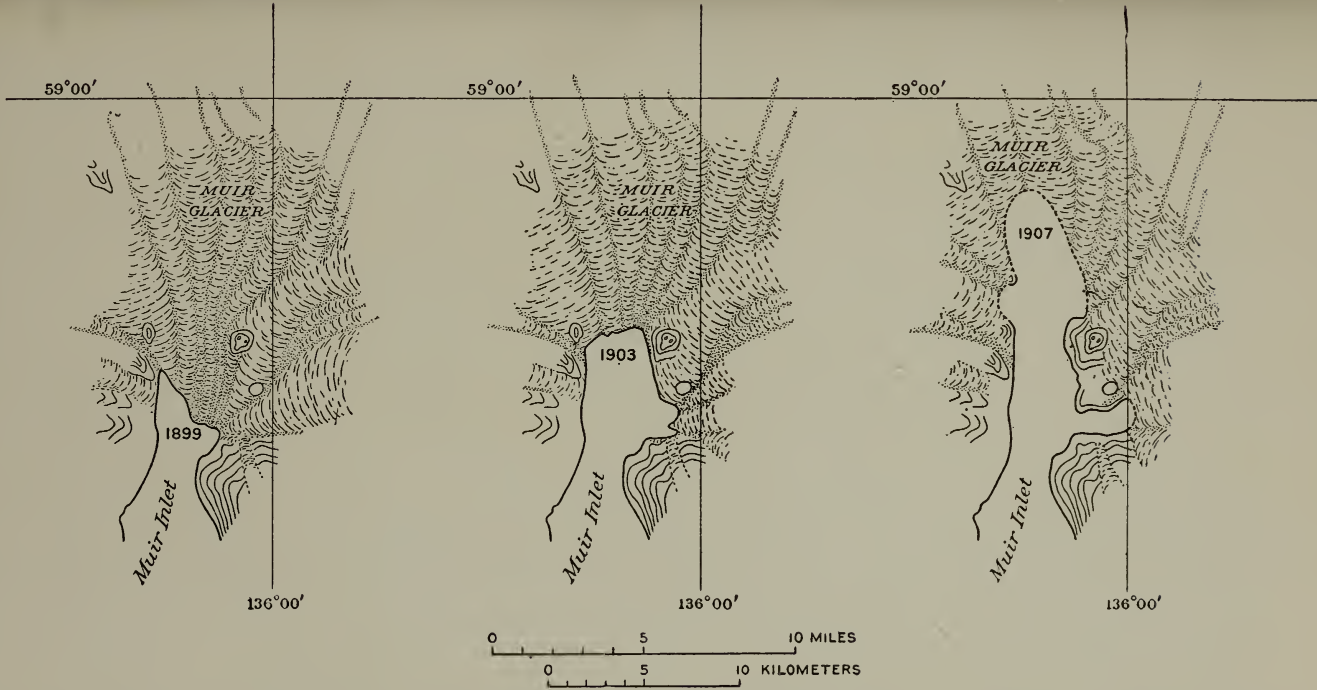
That the latter part of this history is a general one is shown by the following table for Grand Pacific glacier. Most of the other ice tongues in Glacier bay have had a similar history of recent recession.

| Year. | Movement. | Amount. | Rate per year. | Based on observations by |
|---|---|---|---|---|
| 1879 to 1892. | Retreat.... | 21,120 ft. (6,420 m.) | 1,056 ft. (321 m.) | Muir, Reid. |
| 1892 to 1894. | Retreat.... | 2,500 ft. (760 m.) | 1,250 ft. (380 m.) | Boundary Survey. |
| 1894 to 1899. | Retreat.... | 6,600 ft. (2,000 m) | 1,320 ft. (400 m.) | Gilbert. |
| *Earthquake.* | | | | |
| 1899 to 1906. | Retreat.... | 30,360 ft. (9,230 m) | 4,337 ft. (1,318 m) | F. E. & C. W. Wright |
| 1906 to 1907. | Retreat.... | 2,640 ft. (800 m.) | 2,640 ft. (802 m.) | Morse, Klotz. |
| 1907 to Sept. 2, 1911. | Retreat.... | 500-1,000+ ft. (150-300 m.±) | .......... | Tarr and Martin. |
| 1907 to June 1, 1912. | Retreat.... | 10,725 ft. (3,260 m.) | .......... | Ogilvie. |
| June 1 to Aug 1, 1912. | Retreat.... | 6,500 ft. (1,900 m.) | Over 17,000 ft (5,100 m) | Ogilvie. |

## Earthquake Relationships.

It will be noted in these tables that since the 1899 earthquake Muir glacier has retreated seven times as fast, and that the Grand Pacific glacier has receded more than three times as fast as during the previous years.

The earthquakes of September, 1899, were very severe in Glacier bay [**76**], and there was a tremendous increase in icebergs immediately following the shocks, and for the next ten years. Andrews [**1**], Gilbert [**31**], Klotz [**38**], Morse [**60**] and others have ascribed the rapid recession of the glaciers to these earthquakes. F. E. and C. W. Wright [**95**] have not correlated this acceleration with the earthquake effects in September, 1899, but believe




Map of Muir glacier in 1899 (Gilbert and Gannett), in 1903 (Andrews), and in 1907 (Morse and Klotz.) In 1911 Tarr and Martin found that the ice front had retreated about 2000 feet more.

that the great recession of Muir and adjacent glaciers may be largely due to increased melting and iceberg discharge consequent to the rapid retreat, by which the length of Muir ice cliff exposed to the waves was increased from 9,200 feet (2,800 m.) in 1892, to 40,000 feet (12,000 m.) in 1906. Tarr and Martin [**76, 77**] have concluded that the effect of the earthquakes on the recession may have been somewhat exaggerated, for it is certain that a diminution of snow and ice supply is mainly responsible for the rapid changes. The $8\frac{3}{4}$ mile (14 km.) shortening of Muir glacier from 1899 to 1911 was accompanied by 500 to 1,500 feet (150 to 450 m.) of thinning through vertical ablation of the glacier surface, which could not be ascribed to the earthquakes. There is, however, a remarkable coincidence between the date of the earthquake and the beginning of accelerated retreat of the ice tongues of Glacier bay. There is no known change of level of the land to aid in accounting for this.

The recent great advance of the two glaciers of Rendo inlet in Glacier bay raises the interesting question as tu whether Muir glacier and the other ice tongues of Glacier bay will soon readvance. On one hand the maturity of forest growth between the ancient and the second advances suggests that readvance should not commence for a long time; but, on the other hand, the earthquake stimulation introduces a new factor besides that of climatic oscillation. As this factor is yet little known, prediction is unsafe.

ANNOTATED GUIDE.—Continued.

105 m. 168 km **Entrance to Glacier Bay**—Leaving the entrance to Glacier bay we continue in a southwesterly direction through Cross sound to the open Pacific ocean; thence we follow the

130 m. 208 km. **Pacific Ocean**—ccast line in a northwesterly direction. The mountains of the Fairweather range are conspicuous a short distance inland, the prominent peaks named in order from the south being La Perouse (10,756 ft., 3,278 m.), Crillon (12,727 ft., 3,879 m.), Lituya (11,745 ft., 3,579 m.), and Fairweather (15,330 ft., 4,672 m.). Because of heavy snowfall this range is mantled by snowfields and glaciers.

165 m.
254 kn.

**La Perouse Glacier**—If the weather is favourable the vessel will pass within a mile of the terminus of La Perouse glacier which is tidal. This small piedmont glacier was advancing and destroying the adjacent forest in 1895, but had retreated and was inactive in 1899. It advanced about ¼ mile (·4 km.) between September 4th, 1909 and June 10th, 1910. [48]. The adjacent ice masses include several piedmont glaciers and several ice tongues whose termini are mantled by ablation moraine and forest.

185 m.
296 k.m

**Lituya Bay**—Twenty miles (32 km.) to the northwest of La Perouse glacier is Lituya bay, a steep-walled fiord. Fifteen miles (24 km.) along the coast from Lituya bay is the piedmont Grand Plateau glacier. Thence northwestward

200 m.
320 km.

**Grand Plateau Glacier**—to Yakutat bay the mountains are separated from the sea by a coastal plain, Yakutat foreland, which is 70 miles (112 km.) long, 5 to 17 miles (8 to 27 km.) wide, and is made up of terminal moraines and the outwash deposits of former and present day glaciers.

270 m.
432 km.

**Yakutat Bay**—Rounding Ocean cape, the extreme northwestern point of the Yakutat foreland, the steamer arrives in Yakutat bay, and about 5 miles (8 km.) past the point on the south side of the bay is Yakutat village, where there is a tribe of Thlinkit aborigines.

275 m.
440 km.

**Yakutat village.**—

# GEOLOGY AND PHYSIOGRAPHY OF YAKUTAT BAY.

## General Physiography.

Yakutat bay is a deep indentation in the otherwise almost unbroken concave stretch of coast line between Cross sound and Controller bay. This smooth coast is backed by the lofty St. Elias and Fairweather ranges, the former reaching its culminating heights in Mount St. Elias and Mount Logan. The mountains do not rise directly from the sea, but are faced by a low foreland, or coastal plain of glacial debris. Yakutat foreland broadens from the southeast toward the northwest, and on the northwest side of Yakutat bay is still occupied by the ice plateau of the Malaspina piedmont glacier. Yakutat bay, which lies about 40 miles (64 km.) southeast of Mount St. Elias, pierces Yakutat foreland as a broad V-shaped bay. On its west side the bay is bordered by a low foreland of glacial gravels, which are still being deposited by streams issuing from Malaspina and other existing glaciers that lie behind the narrow strip of gravel and moraine.

On the east and southeast side of Yakutat bay the foreland forms the coast for about half its length only. This part of the southeastern shore line is very irregular and is fronted by an archipelago of low islands composed of glacial debris. The northern half of the bay has for its eastern shore the Brabazon hills, which rise abruptly to elevations of 3,000 to 4,550 feet (900 to 1,380 m.). This shore is straight and precipitous, and the mountain front against which the foreland is built also rises abruptly along a straight line which truncates the mountain spurs.

Yakutat bay merges northward into a narrow arm called Disenchantment bay, a fiord walled on both sides by steep mountains. It extends from Points Funston and Latouche on the south, to Hubbard glacier on the north. Thus its head is an ice wall from 4 to 5 miles (6 to 8 km.) in length, the terminus of the largest glacier in the region except the piedmont ice mass of Malaspina glacier. A second tidal glacier, the Turner, enters this part of the fiord through a valley in its west wall.

At Hubbard glacier the inlet turns sharply, and thence on to its head it is called Russell fiord. Close by, to the north, northeast, and northwest, mountains rise


View of model of region including Yakutat bay and Malaspina glacier.

to elevations of 10,000 to 16,000 feet (3,000 to 4,800 m.); but along the immediate shores of the fiord the mountains, though abrupt, rise only from 2,000 to 6,000 feet (600 to 1,800 m.). Russell fiord, which extends back toward the Pacific roughly parallel to Disenchantment and Yakutat bays, is divisible into three sections:—(1) a northwest arm, with straight mountainous shores; (2) a longer south arm, with a much more irregular mountainous shore line, and (3) the head of the bay, an expanded extension of the inlet where it passes beyond the mountain front out into the foreland. A small bay, Seal bay, up whose valley lies Hidden glacier, forms the greatest irregularity in the coast line of the south arm; but at the angle between the south and northwest arms a large fiord known as Nunatak fiord, extends eastward. The tidal Nunatak glacier forms its head.

The entire inlet—Yakutat bay, Disenchantment bay, and Russell fiord—has the general shape of a bent arm, with the shoulder at the Pacific, the elbow at the head of Disenchantment bay, and the fist at the expanded head of the bay, which lies within 13 or 14 miles (20 to 22 km.) of the ocean. The distance by boat from the ocean around to the head of Russell fiord is 70 miles (112 km.).

Everywhere are indications that the inlet is deep. Soundings by the United States Coast Survey in outer Yakutat bay show an irregular bottom deepening toward Disenchantment bay. At the mouth of the latter, near Point Latouche, there is a depth of 167 fathoms or 1,002 feet (304 m.); and Russell reports 40 to 60 fathoms (70 to 109 m.) between Haenke island and Hubbard glacier. Soundings made by the author in 1910 show that Disenchantment bay and Russell fiord are uniformly deep, attaining maxima of 939 and 1,119 feet (285 and 340 m.) respectively.

## General Geology. [65, 66, 72.]

The northeastern shore of Russell fiord, from Hubbard glacier to Nunatak fiord, is bordered by highly-inclined slates of Paleozoic or Pre-Cambrian age. Excursions into the mountains along this shore reveal a variety of crystalline rocks, both igneous and metamorphic, and the glaciers bring down only rock of these classes. It is therefore inferred that the rocks in the mountains beyond the

head of Disenchantment bay and the northwest arm of Russell fiord are all crystalline. All the north shore and the eastern two-thirds of the south shore of Nunatak fiord are also bordered by crystalline rocks—granite and steeply-dipping gneiss, schist, slate and schistose conglomerate with stretched pebbles.

These crystalline rocks abut abruptly against younger, practically unmetamorphosed strata, both in Hidden Glacier valley and on the south shore of Nunatak fiord. This line of separation, interpreted as a fault, would, if continued, extend along the northwest arm of Russell fiord, on one of whose shores the rocks are crystalline, whereas on the other (the southwest), they are unmetamorphosed.

From the area of crystalline rock to the foreland a complex of strata, the Yakutat system of Russell, forms all the mountains that border this part of the fiord. These strata consist of thin-bedded black shales and sandstones, thick beds of conglomerate, and a massive gray sandstone or greywacke, which, in some parts at least, is an indurated tuff. There are other beds in lesser amounts, and the entire mass is complexly folded and faulted, both on a large scale and in detail. Some faults and folds occur in all the outcrops, and a score or more may appear in a single outcrop a few square yards in area. The rocks are literally crushed and kneaded. The Yakutat system is nearly barren of fossils, and it has not been possible to determine its age from those collected. There are some indications that they are of Mesozoic age, and some that they are older. Ulrich [**32.**] has classed them as Liassic.

A third series of rocks was found in a few outcrops on the west side of the Yakutat bay, 2 or 3 miles (3 to 5 km.) from the mouth of Disenchantment bay and just outside the mountain front. These rocks are mainly gray sandstones, clays, and carbonaceous shales, with a few thin beds of lignite coal. They are tilted at a high angle, but are not as complexly folded and faulted as the Yakutat system, from which they are generally separated by a fault. On the basis of fossil plants they are assigned to the Pliocene epoch.

Outside of the mountain front, as already stated, the foreland of glacial gravels extends to the sea; but near the head of Russell fiord it is underlain by planated beds of the Yakutat system and granitic rocks. No indurated rock was found elsewhere in the foreland; though a low, butte-like hill, that rises above it some distance from the mountains, is evidently composed of rocks of the same system.

## THE 1899 EARTHQUAKE.

In September 1899 Alaska was disturbed by a series of world-shaking earthquakes, [**46, 47.**] the greatest of which are known to have been felt throughout 216,300 square miles (560,600 sq. km.) on the land and which may have been sensible in an area of a million and a half square miles (3,880,000 sq. km.) The principal shocks came on September 3, 10, 15, 17, 23, 26, and 29. They were recorded by all seismographs then in operation throughout the world.

Most of these shocks were central in Yakutat bay. They were felt with the greatest severity by seven prospectors who were encamped close to a fault line in Russell fiord near Variegated glacier, by the inhabitants of Yakutat village only 30 miles (48 km.) away, and by many others in Alaska, Yukon and British Columbia.



Barnacles and mussels attached to the ledges uplifted in the 1899 earthquake.

During the second severe shock on September 10 there was renewed movement along old fault lines in the Yakutat Bay region, resulting in the tilting of large fault blocks and disturbance of the shorelines. The changes

Photograph of parallel step faults near Nunatak glacier.



Photograph of one fault with throw of $4\frac{1}{2}$ feet, made in 1899 earthquake.

in the level of the coast are relatively great, and may be measured by the barnacles, mussels, bryozoa, and other marine forms attached to the rocks, as well as by the abandoned shorelines themselves.

The uplifted shorelines include sea cliffs, caves, rock benches, skerries, and new islands in the rock; and gravel benches, sand dunes, deltas, and spits in the unconsolidated shore accumulations. There are also present-day shorelines of till as a result of the uplift. The amounts of uplift are from 1 to 12 feet (1·3 to 3·6 m.) in outer Yakutat bay, from 7 to 47 feet (2 to 14 m.) in Disenchantment bay, and from 2 to 10 feet (·6 to 3 m.) in Russell fiord. From the distribution of these uplifts seven fault lines have been located.

On the downthrown side of certain of these faults the coast was depressed, and trees were killed by submergence. The depression was from 5 to 7 feet (1·5 to 7·1 m.) especially in the extreme southern end of Russell fiord and on the eastern side of outer Yakutat bay near Knight island and Logan beach.

The region furnishes clear evidence of older uplift and depression in connection with earlier faulting.

The 1899 earthquakes also resulted in the production of sand vents and furrows, in destructive water waves, and in minor faults within some of the larger fault blocks. These minor faults are best seen on the rock hill near Nunatak glacier where there are scores of fault scraps with vertical hade, and throws from a few inches to eight feet (2·4 m.), 26 parallel step faults having an aggregate throw of 30½ feet (9·3m.).

During the earthquake there was minor shattering of glaciers, and vast numbers of rock avalanches and snowslides, the latter resulting in a series of brief spasmodic advances of certain of the glaciers, as described on a later page.

## Present-day Glaciers. [78]

On the western side of Yakutat bay is Malaspina glacier, a vast ice plateau made by the union of the piedmont bulbs of several large glaciers and many smaller ones. Most of its periphery is covered by ablation moraine, and in places this moraine supports a forest of alder, cottonwood, spruce and hemlock. The easternmost tributary to the Malaspina is Hayden glacier, which contributes little

Photograph of elevated sea cliff and rock beach on eastern side of Haenke Island, hoisted 17 feet 7 inches in 1899 earthquake.

ice. Just west of the Hayden the great Marvine glacier descends from the mountains and supplies the ice which forms the eastermost of the four lobes of Malaspina glacier. The low ice cliff of this glacier lies just back of the west coast of Yakutat bay, extending from near Point Manby to the Kwik river, and being separated from the sea by a fringe of alluvial fans across which flow many large, swift, glacial streams. The Marvine lobe of the Malaspina glacier is of distinct present interest because of a change

Excursion C 8.


Three of the largest ice tongues of the Swiss Alps superposed on the same scale over Hubbard glacier.

from stagnation to activity between 1905 and 1906. The other three lobes of Malaspina glacier, called Seward, Agassiz, and Guyot, are fed by valley glaciers of the same names.

East of the Malaspina glacier, and between it and Yakutat bay, are three glaciers which extend beyond their

Photograph of Hubbard glacier and 10,000 to 16,000 foot peaks of St. Elias range, from crest of Haenke island in 1910.

mountain valleys and spread out in piedmont bulbs. The largest and westernmost of these, the Lucia, is now separated from Malaspina glacier, of which it was undoubtedly a former tributary, only by the gravels of the valley train and delta of Kwik river. Immediately east of the Lucia, and coalescing with it, is the piedmont bulb of Atrevida glacier. Both of these bulb glaciers are covered with ablation moraine, and on their outer, stagnant termini, support a forest of alder, cottonwood and spruce. Atrevida glacier changed from stagnant to active condition between September 1905 and June 1906, and Lucia glacier in 1909. Galiano glacier, the smallest of these three, changed from stagnation to activity between 1890 and 1905, probably after 1895 and almost surely after 1899. Its piedmont bulb extends practically to the shores of Yakutat bay from which it is separated only by a gravel beach. Two or three miles (3 to 5 km.) to the east of the Galiano glacier is the still smaller black glacier, which has no piedmont bulb, and is especially interesting because, though so near the Galiano, it gives no evidence of having undergone notable change in condition for the last quarter century.

On the west side of Disenchantment bay is the larger Turner glacier, a tidal glacier with an ice cliff $2\frac{1}{2}$ miles (4 km.) in length, which, though changed slightly each time it has been observed, shows no such pronounced variation in condition as those just mentioned. Just north of it, however, is a smaller ice tongue, called Haenke glacier, which, like the Atrevida, was absolutely transformed between 1905 and 1906. It became broken, advanced nearly a mile, and assumed tidal conditions in ten months. Just north of this is another unnamed glacier, which had a similar period of crevassing and advance in 1901.

Next is the Hubbard glacier, the largest tidal glacier in the region, which is fed by two large tributaries from some unknown source far back among the mountains and has a tidal front $5\frac{1}{2}$ to 6 miles (8 to 10 km.) in length. It presents many interesting features, and in 1909 had a slight advance. Variegated glacier, whose piedmont ice bulb coalesces with the southeastern side of the Hubbard, presents the interesting condition of a piedmont bulb in a valley instead of at the base of the mountain front. It rivals Atrevida and Lucia glaciers in its ablation moraine, though it lacks forest growth on the larger part of it; and equals Atrevida glacier in the extent of its transformation

between 1905 and 1906. Almost coalescing with the Variegated, is Orange glacier, entirely confined in its mountain valley, unchanged since first observed in 1905, and forming the western end of a through glacier, whose other end is just back from the shore of Nunatak fiord. Near the southeastern end of this through glacier, Butler glacier descends from the mountains, and, emerging from its mountain valley, spreads out, as Variegated glacier does, into a moraine-covered piedmont bulb occupying a broad valley mouth almost on the shores of Nunatak fiord.

Just east of this piedmont ice bulb is the ice cliff on the tidal Nunatak glacier, whose history from 1891 to 1909 was that of continuous recession for over 2½ miles (4 km.), followed by an advance of 700 to 1,000 feet (200 to 300 m.) between 1909 and 1910. It has also a wasting land tongue or distributary, and above its end hangs the ice fall of Cascading glacier, the type of a series of similar glaciers in this region and elsewhere in Alaska. On the north side of the fiord is Hanging glacier, which no longer cascades over the lip of its hanging valley. Hidden glacier, to the southwest of Nunatak glacier, was of peculiar interest in 1899 and 1905 because of the valley train which separated its stagnant terminus from the sea. These outwash gravels rested for a distance on the glacier ice, which, by melting, gave rise to a pitted plain. All this is now destroyed, for in 1909 Hidden glacier was utterly transformed, having undergone a spasmodic advance of over 10,000 feet (3,000 m.) since last seen in 1906.

## Ancient Expansion of Yakutat Bay Glaciers.

Throughout the entire Yakutat Bay region the evidence is complete that all the glaciers have been far more extended at a former period than at present [**72, 73**]. The period of greatest extension of the glaciers was recent, in a geological sense, but was several centuries ago, for a mature forest grows on the deposits laid down by these expanded glaciers.

There are several lines of evidence for concluding that these glaciers were formerly far greater than now. In the first place, the valleys throughout the region show clear signs of pronounced glacial erosion. The valley walls are scored, grooved, polished and smoothed to elevations far above sea level, and, in those valleys where


Geological Survey, Canada

**Nunatak Glacier**

(Reproduced by the permission of The National Geographic Society)

Miles 3/4 1/2 1/4 0 1

Kilometres 3/4 1/2 1/4 0 1 2

(Soundings and elevations shown in feet)


Geological Survey, Canada.

Hidden Glacier

(Reproduced by permission of
The National Geographic Society)

Miles

Kilometres

(Soundings and elevations shown in feet)

glaciers still linger, to elevations far above the surfaces of the present glaciers. Tributary valleys hang above the level of Yakutat bay, Disenchantment bay, Russell fiord, and Nunatak fiord; secondary tributaries to these lateral valleys hang above them; and hanging valleys, often with cascading glaciers, lie above the level of the surfaces of all the larger existing glaciers. Many of these glaciers head in cirques, except in the case of the through glaciers.




Photograph of Nunatak glacier from crest of Nunatak, showing retreat from 1905 to 1909, and advance from 1909 to 1910. Subsequently there has been a retreat of ¼ mile.

A second evidence of former expansion is the presence of outwash gravels along the shores of the fiord even as far as the mouth of Yakutat bay, in places where glaciers are no longer present or depositing.

The third proof is the distribution of transported rock fragments and the development of morainic terraces at elevations high above the level of the inlet, and high above the surfaces of such glaciers as are present. Such deposits occur all along the shores of the inlet, to the west of Yakutat bay above the eastern margin of Malaspina

glacier, and in the valleys of the larger glaciers which come down to Yakutat bay. The moraine terraces—the hummocky moraine which forms the southeastern margin of Yakutat bay, as far out as the village of Yakutat, the similar moraine about the head of Russell fiord and the crescentic deposit which extends as a submarine ridge across the mouth of Yakutat bay—descend in the direction of the ocean, and are evidently of former glacier expansion.

From these four lines of evidence it has been concluded that at the period of the greatest expansion, all the glaciers were much larger than now. Malaspina glacier then rose much higher on the slopes of the mountains west of Yakutat bay, its tributaries were greater, it received tributaries, notably, Lucia and Atrevida, that are now disconnected, and it coalesced with a great glacier that filled Disenchantment bay and Yakutat bay out as far as Yakutat village and the submerged moraine that stretches in crescentic form westward to Point Manby. To this expanded glacier that filled Yakutat bay, the name Yakutat Bay glacier has been given; and the similar expanded glacier in Russell fiord has been called Russell fiord glacier. The latter glacier completely filled Russell Fiord and terminated in a piedmont bulb on the inner edge of the foreland, where it has left a crescentic moraine from which outwash gravels slope seawards.

## Second Expansion of Glaciers.

Since the ancient period of maximum glacier expansion, and far more recently, there has been a second advance, amounting to at least 20 miles (32 km.). The united Hubbard and Turner glaciers, joined by others pushed into Disenchantment bay and southeastward into Russell fiord, while Nunatak glacier, coalesced with Hidden glacier and others and pushed northwestward into the northwest arm of Russell fiord, and southward into the south arm for about two thirds of the way to the head of the bay. During this advance a lake was formed in the southern end of Russell fiord where its shoreline is still visible. This advance of the glacier was of such brief duration and such moderate intensity that the ice erosion did not succeed in removing the gravels previously deposited. Hence it contrasts strikingly with the earlier, prolonged advance by which the bed-rock was scoured out to a depth of many

Photograph of Nunatak glacier in 1909 from cairn on northern side of fiord.

hundred feet by the powerful erosive action of the expanded glaciers. Between these two ice advances there was a long interval, during which the glaciers receded even farther than at present, and forest growth extended throughout the fiord and even up the valleys now occupied by the glaciers. The last advance terminated only a short time ago, and the recession from this stage of advance was apparently still in progress as late as 1905. The recency of the last advance, and of the ice recession from that stand, is proved by the condition of the vegetation growing in the area occupied by the ice. In the outer portion of the area covered by the expanded glacier, a dense growth of mature alder and some cottonwood covers the overridden gravels, but the growth rapidly decreases in amount and density toward the glaciers. In Seal bay and Nunatak fiord there are only scattered individual plants, and the density of alder growth gradually increases toward the portions of the inlet where the expanded glaciers ended. In other words, this period of ice advance was so recent that only a part of the area is as yet occupied by vegetation, and the outer portion is occupied only by the advance growth of alder and, in the extreme south of cottonwood. The spruce forest of the Alaskan coast has not yet had time to advance upon the region from which the glaciers have so recently receded.

The date of this second advance is not known, but the vegetation suggests that it was not over a century or two ago. Russell [**65**] and Davidson [**72**] have each interpreted the maps and descriptions of Malaspina and Vancouver as indicating that the front of Hubbard glacier was as far south as Haenke island in 1792 and 1794. Tarr and Martin [**26**] are not in agreement with this interpretation as to the exact date of the expansion.

Tebenkof's Atlas of Alaska, [**79**] however, actually shows the lake in southern Russell fiord, as indicated by a map of Khromtchenko in 1823. This may have been based upon a report from natives and may indicate conditions some time before 1823. It is, therefore, impossible to say exactly when the re-advance of the glaciers took place.

Four photographs from exactly the same site (cairn), showing Nunatak glacier in 1899 (Gilbert), 1905 (Tarr and Martin), 1906 (Tarr), and 1910 (Martin).
Recession of 9,900 feet, $1\frac{7}{8}$ miles or 3 kilometres.

## Modern Recession of Glaciers.

In Russell's visits to the Yakutat Bay region in 1890 and 1891 he found the glaciers in a state of general recession. Gilbert's observations in 1899 led him to the same conclusion, and Tarr and Martin's observations in 1905 showed that the glaciers were still wasting away. The evidence of this condition of recession is partly from inference, based upon the characteristics of the glaciers and the conditions at their borders, and partly from the direct comparison at the later dates with observations made during the earlier studies. Russell, Gilbert, and Tarr and Martin have all noted the fact that many of the glaciers are covered at their lower ends by ablation moraine and that in some of the more stagnant portions these ablation moraines bear forests. From this condition the inference is perfectly warranted that the glaciers in these regions are receding. More specific, however, is the evidence around the glacier borders, both at the sides, and, at the fronts of those which end on the land. While forest, or at least alder, extends up nearly to the front of many of the glaciers, and also grows on the valley sides above them, there is, near many of the glaciers, a zone at the front and just above the ice surface, which is barren of vegetation. From such a condition one infers that the ice has withdrawn from such areas so recently that vegetation has not yet had time to encroach upon it. The extent of shrinkage indicated by this class of evidence varies with different glaciers, but it is present to some degree in the neighborhood of almost all the glaciers studied, and in some it indicates a great and long-continued shrinkage. This is particularly true in Nunatak and Russell fiords, as already stated in the preceding section. Here it is certain that in the last century the resession has amounted to many miles.

## Recent Advances of Nine Glaciers.

In 1905 Tarr and Martin found that, while the general condition of recession characterized the great majority of the Yakutat Bay glaciers, Galiano glacier presented convincing evidence of change to activity in the interval since it was photographed by Russell in 1890. Then it had a stagnant piedmont bulb on whose ablation moraine

Variagated glacier with covering of ablation moraine and its interior flat.

a dense forest of alder and cottonwood grew, proved both by Russell's description and his photographs and also shown by Boundary Survey photographs in 1895. This had entirely disappeared in 1905, but the piedmont bulb was again stagnant and covered by ablation moraine, though with only young alders scattered here and there. Neighbouring glaciers, for instance Atrevida, the nearest to the west, and Black glacier to the east, gave no evidence of similar change, and no such evidence was found in any other glaciers, though it was found later that the small ice tongue north of Haenke glacier had a period of crevassing and advance in 1901.

In 1906 Tarr found four glaciers absolutely transformed and all the others unchanged. The glaciers that were so altered in the brief interval of ten months are, named from west to east: (1) Marvine glacier and the eastern lobe of Malaspina glacier that is supplied by the Marvine; (2) Atrevida glacier; (3) Haenke glacier; and (4) Variegated glacier. In the summer of 1905 one could travel upon the surfaces of these glaciers at will. On two of them, Atrevida and Variegated glaciers, Tarr and Martin walked freely, on the former late in August, without recognizing any signs of coming change to activity, though Martin saw signs of the beginning of advance in the Marvine lobe of Malaspina glacier. They were crevassed slightly only here and there, and outside their mountain valleys, were in a stagnant or semi-stagnant condition and covered with a waste of ablation moraine; but in June, 1906, all four glaciers were transformed to a sea of crevasses and not only was it impossible to travel over their surfaces, but it was not even possible to climb up on the glaciers except by the most difficult ice work. Furthermore, the glaciers were even then actively advancing, and the advance extended out even to the fully stagnant margins, overturning forests of alder and cottonwood that were growing on the outer portions of Malaspina and Atrevida glaciers. Not only were the ice surfaces broken by a maze of crevases, but the margins, which had hitherto been gently-sloping, moraine-covered ice banks, were transformed to steep ice cliffs crowned by bristling ice pinnacles. The margins were pushed forward, and the heretofore stagnant piedmont bulbs were thickened. Haenke glacier had advanced to tidal condition; Atrevida and Malaspina glaciers were pushing into the forest that fringed their margin, and Variegated glacier has become notably thicker

and had crowded out over a rock gorge, destroying the glacial stream that had occupied it in 1905.

It was evident from these facts that the glaciers in question had been subjected to some unusual impulse that had caused a sudden forward rush, which had pushed them forward, thickened them and greatly broken their surfaces. In seeking an explanation for such a phenomenon, not hitherto recorded, but one cause seemed adequate, namely, the severe earthquake shocks to which this region was subjected in 1899. Tarr advanced the hypothesis that the repeated violent shaking during the earthquakes that occurred between September 3 and 29 threw down so much snow into the reservoirs of the glaciers, that a wave of motion was started which reached completely down to the terminus of Galiano glacier some years before 1905, and which was passing down the four other glaciers during 1906. In testing this hypothesis with the facts available, all were found to be in harmony with it, none were discovered that were opposed to it, and no other hypothesis could be suggested which had no facts fatal to it.

While, therefore, the hypothesis of earthquake cause for this advance seemed well supported, it was desired to subject it to still further test, and one of the main objects of the work in 1909 and 1910 was to apply these tests. There were three such tests which Tarr and Martin had especially in mind. In the first place, if the advance were due to this cause, it should be confined to the general region of violent earthquake shaking. By inquiring about the condition of glaciers southeast of Yakutat bay, and by studying some of the glaciers of the Prince William Sound region to the northwest, they were able to apply this test to some extent, but not fully enough to warrant a definite statement of its adequacy in support of the hypothesis.

The second test is the behaviour of other glaciers in the Yakutat Bay region in the years since 1906. If the hypothesis were correct, probably some of the smaller glaciers of Yakutat bay had advanced before 1905, and certainly some of the other glaciers of the region ought to show signs of the wave of advance. This was predicted by Tarr [**72**] in 1906. There is reason to believe that there was an advance of some of the smaller glaciers before 1905, though it is now difficult to obtain convincing evidence, but that the wave of advance had extended to other glaciers between 1905 and 1909 was strikingly illustrated by Hidden glacier [**75**], which had advanced two miles (3.2 km.) and

become greatly broken, by Lucia glacier, which was actively advancing and was completely transformed by crevassing during the summer of 1909, less strikingly by Hubbard glacier, whose eastern margin had a slight advance in 1909, and by Nunatak glacier, which had advanced 700 to 1,000 feet (200 to 300 m.) when visited by Martin [**47**] in 1910.



The ice of Variegated glacier, covered with ablation moraine and small shrubs.

The third test was a cessation of advance in those glaciers that moved forward in 1906. With a sudden, great addition of snow quickly terminated and followed by a spasmodic advance of the glaciers thus supplied, it would be expected that the wave of advance would soon die out and the condition of stagnation return. This also was predicted, and the observations of 1909 show clearly that the prediction was correct, for all the advancing glaciers of 1906 had returned to a condition of stagnation in 1909, and the crevasses in the broken ice had been so healed by ablation that it was once more possible to travel over the glaciers though with far less ease than in 1905. Martin [**47**] found that Lucia and Hubbard glaciers likewise had

ceased to advance in 1910, and the 1910 advance of Nunatak glacier had practically ceased when the glacier was visited by N. J. Ogilvie of the Canadian Boundary Survey party of 1911; by 1912 he found that the tidal ice cliff of this glacier had retreated about $\frac{1}{4}$ mile (.4 km.).

It is believed that the observations of 1909, 1910, and subsequent years furnish what further facts are necessary to demonstrate the hypothesis put forward by Tarr in 1906 [**72**], and that the explanation may now be stated with confidence, as an established hypothesis,—a new cause for glacier advance. The sudden forward rush of a

Excursion C 8.

Elevated beach and sea cliff in Russell fiord, hoisted over 7 feet in 1899 earthquake.

glacier accompanied by pronounced thickening and extensive surface breakage may be called a glacier flood, and the resemblance to a river flood is noteworthy. When heavy rainfall, or unusual melting of snow occurs in the headwater region of a river, a wave of rising, rapidly down-moving water is started which may cause a flood all along the stream course. If a portion of the river is ice covered, the rigid ice crust will be shattered and heaved into a maze of

broken ice blocks; but under ordinary conditions the river behaves more normally, slowly rising and falling with variation in supply. So in a glacier, under ordinary conditions variations in supply manifest themselves in moderate advance or recession; but when a deluge of snow and ice is thrown down in its upper reaches the conditions for a spectacular advance,—a glacier flood—are introduced. The ice stream flows on more rapidly, its rigid outer portion is cracked and broken, its surface rises, its width increases, and its front is pushed forward. There is, however, a striking difference in the time occupied by the two classes of floods. A river flood passes from the source to the mouth of the river in a few hours or a few days, and its effects are over in a few hours or a few days; but the far less mobile ice requires several years for the transmission of a glacier flood, and its duration is months long, while years are required to bring the ice surface back to its pre-flood state.

The recent advances of the nine Yakutat bay glaciers just described may be arranged as follows, when it is seen that the date of advance is directly related to the length of the glacier, the shortest ice tongues advancing first [**47**].

| Glacier. | Date of Advance. | Length of Glacier. |
|---|---|---|
| Galiano | After 1895 and before 1905. | 2 or 3 miles (3 to 5 km.) |
| Unnamed glacier* | 1901 | 3 or 4 miles (4 to 6 km.) |
| Haenke | 1905–6 | 6 or 7 miles (9 to 11 km.) |
| Atrevida | 1905–6 | 8 miles (12·8 km.) |
| Variegated | 1905–6 | 10 miles (16 km.) |
| Marvine | 1905–6 | 10 miles (16 km.)** |
| Hidden | 1906 or 1907 | 16 or 17 miles (25 to 27 km.) |
| Lucia | 1909 | 17 or 18 miles (27 to 29 km.) |
| Nunatak | 1910 | 20 miles (32 km.) |

* Between Haenke and Hubbard glaciers.
** Excluding expanded lobe on Malaspina.

Our Alaskan glaciers within the area vigorously shaken in September, 1899, [**76.**] which subsequently have had short vigorous periods of activity, accompanied by severe crevassing and advance, that interrupted a period of stagnation or slighter activity, are listed below. Some of these should certainly be added to the list of nine glaciers which we know to have advanced as a result of the earthquakes in 1899.

| Glacier. | Distance and direction from Yakutat bay. | Year of activity. | Amount of advance. | Described by |
|---|---|---|---|---|
| Norris | 225 miles (360 km.) southeast. | 1904 | | F. E. & C. W. Wright. |
| Taku | 225 miles (360 km.) southeast. | Between 1890 and 1905. | | H. F. Reid. |
| In Lituya bay | 120 miles (190 km.) southeast. | Between 1894 and 1906. | ½ mile (·8 km.) | F. E. & C. W. Wright. |
| Childs | 190 miles (300 km.) west | 1905–1906 | | Lawrence Martin |
| Valdez | 240 miles (380 km. northwest. | Between 1905 and 1908. | 250 to 350 feet (75 to 100 m.) | U. S. Grant. |
| Miles | 190 miles (300 km.) west | Between 1908 and 1910. | 1,800 to 4,000ft. (500 to 1,200m-) | Lawrence Martin. |
| Shoup | 250 miles (400 km.) northwest. | About 1900 or 1901 | | U. S. Grant. |
| Alsek | 75 miles (120 km.) southeast. | Between 1906 and 1908. | | Fremont Morse. |
| In Alsek valley | 55 miles (88 km.) east | 1908 | | Fremont Morse. |
| Near Frederika glacier | 150 miles (240 km.) northwest. | 1908 | | S. R. Capps. |
| Russell | 145 miles (232 km.) northwest. | Between 1891 and 1908. | | S. R. Capps. |
| Nizina | 155 miles (248 km.) northwest. | 1909 | | S. R. Capps.<br>S. R. Capps. |
| In Alsek valley | 70 miles (112 km.) southeast. | 1909 | | Tarr and Martin. |

| Glacier. | Distance and Direction from Yakutat bay[1] | Year of activity. | Amount of advance. | Described by. |
|---|---|---|---|---|
| Rendu | 120 miles (190 km.) southeast. | Between 1907 and 1911. | Over $1\frac{1}{2}$ miles (2·4 km.) | Tarr and Martin. |
| Adjacent cascading glacier | 120 miles (190 km.) southeast. | 1911 | $\frac{1}{4}$ mile (·4 km.). | Tarr and Martin. |
| La Perouse | 130 miles (208 km.) southeast. | 1910 | Over $\frac{1}{4}$ mile (·4 km.) | Lawrence Martin. |
| Childs | 190 miles (300 km.) west | 1910 | 2,000 ft. (600m) | Lawrence Martin. |
| Grinnell | 190 miles (300 km.) west | 1910 | ... | Lawrence Martin. |
| Rainy Hollow | 120 miles (190 km.) east | Between June and September, 1910. | 2,000 ft. (600m) | Webster Brown. |
| Chitistone | 135 miles (216 km.) northwest. | 1911 | $\frac{1}{2}$ mile (·8 km.) | R. F. McClellan. |
| Heney | 190 miles (300 km.) west | 1911 | ... | Lawrence Martin. |
| Allen | 190 miles (300 km.) west | 1912 | $\frac{1}{2}$ mile (·8 km.) | Caleb Corser. |
| Logan | 80 miles (128 km.) northwest. | 1912 | ... | D. W. Eaton. |

It is not known whether all these advances were climatic or whether some were due to earthquake avalanching. That the two sorts of advances may be distinguished when observations are made at the right time is indicated by the fact that a general advance of the glaciers of Prince William sound, which began with the 1600 to 1700 foot (480 to 500 m.) advance of Columbia glacier in 1908 (lasting until 1911 or later), and was continued in 1910 by the advance of 14 other glaciers, seems to be climatic rather than a result of the earthquakes of 1899 or that of October, 1900, or any later seismic disturbance. The 15 Prince William Sound ice tongues (Columbia, Meares, Yale, Harvard, Radcliffe, Smith, Bryn Mawr, Vassar, Wellesley, Barnard, Baker, Cataract, Roaring, Harriman, and Blackstone) which were advancing synchronously when observed by Martin in 1910 are of variable lengths and sizes, and in three years the Columbia has not advanced as much as the Childs advanced in less than one year, under the earthquake impulse, nor is its crevassing so severe. Its rate of motion increased from nine-tenths of a foot (·27m.) a day in 1908, to 2 1-10 feet (·63m.) a day in 1910. Of those listed above as advancing between 1899 and 1912 Childs and La Perouse, and probably Rendu and Rainy Hollow glaciers, became suddenly crevassed, advanced great distances, and as suddenly ceased their activity, in these respects strongly resembling the nine Yakutat Bay advances. Childs glacier increased its rate of motion from about 6 feet (1·8m.) a day in 1909, to 40 feet (12m.) a day in 1910, and as suddenly slowed down again. It is realized that all the features of earthquake-generated advances are not yet known; but, when full information is available, such advances should be readily distinguished from climatic oscillations. Perhaps many or all of the advances listed above are of the earthquake-avalanche type, and in that case future advances may be expected in such of the longer ice tongues in the severely-shaken portions of the St. Elias, Fairweather, Coast, Chugach, Wrangell, and Alaska ranges as have steep slopes and other conditions favourable for the earthquake-avalanche type of advance. Earthquake avalanching may even be responsible for most large oscillations of mountain glaciers, as for example in the Himalaya and other youthful, snow-capped mountains which are still frequently faulted and shaken by seismic disturbances.

Still other Alaskan glaciers, in portions of the territory frequently shaken by severe earthquakes, have had earlier periods of unusual activity and advance within historic times. Some of these are listed below and there are doubtless many others. For each of these the hypothesis may be considered that earthquake avalanching during one or another of the great periods of seismic distubrance may have caused the advance, or that some of the advances may have been due to climatic variations and others to earthquakes. The lists shows clearly that the series of great glacial advances in the Yakutat Bay region since 1899 is not exceptional and that the relationship of earthquakes to variations of glaciers may be one common, not only in Alaska, but elsewhere in the world as well.

| Glacier. | Year of activity. | Amount of advance. | Described by. |
|---|---|---|---|
| In Lituya bay........ | Betw'n 1786 and 1894. | 2½ miles (4 km.) | Otto Klotz. |
| In Lituya bay........ | Betw'n 1786 and 1894. | 3 miles (4.8 km.) | Otto Klotz. |
| Brady............... | Betw'n 1794 and 1880. | 5 miles (8 km.) | John Muir. |
| Portage............. | Betw'n 1794 and 1880. | 1 to 3 miles (1.6 to 4.8 km.) | Lawrence Martin. |
| Baker............... | Before 1800 . | .......... | Lawrence Martin. |
| Serpentine........... | Before 1817 . | .......... | Lawrence Martin. |
| Toboggan........... | Before 1840 . | .......... | Lawrence Martin. |
| Western Malaspina .. | Betw'n 1837 and 1880. | About 20 miles (32 km.) | Lawrence Martin. |
| Serpentine........... | Before 1882 . | .......... | Lawrence Martin. |
| Western Malaspina (Guyot).......... | 1886–1888... | .......... | H. W. Seton-Karr. |
| Nellie Juan.......... | Probably before 1887. | .......... | U. S. Grant. |
| Toboggan........... | Before 1889 . | .......... | Lawrence Martin. |
| Baker............... | Before 1891 . | .......... | Lawrence Martin. |
| Eastern Malaspina.... | Before 1891 . | Over 1,500 ft. (450m.) | I. C. Russell. |
| Muir................ | Before 1890 and 1892. | 300 yards (270 m.) | H. F. Reid. |
| Fredericka........... | 1891........ | .......... | C. W. Hayes. |
| Patterson............ | 1891........ | .......... | H. F. Reid. |
| Columbia............ | About 1892.. | .......... | G. K. Gilbert. |
| La Perouse.......... | 1895........ | .......... | G. K. Gilbert. |
| Columbia............ | About 1897 | .......... | G. K. Gilbert. |
| Barry............... | 1898........ | .......... | Lawrence Martin. |


Panorama of Hidden glacier from hill near sea.

With these facts in mind it is reasonable to predict the advance of other and longer glaciers in the Yakutat Bay region as a result of avalanching during the 1899 earthquakes, for, just as the several Alsek glaciers, 55 to 75 miles (88 to 120 km.) east of Yakutat bay, and the Logan glacier, 80 miles (128 km.) to the northwest, advanced in 1908, 1909, and 1912, respectively, so the other and longer ice tongues of the St. Elias range will eventually feel this impulse and push forward. In 1913 for instance, Seward glacier may move forward. This glacier heads on the divide with Logan glacier which advanced in 1912 after at least 200 years of stagnation. A strong advance of Seward glacier would break up the central, stagnant portion of the Malaspina and change the dirty, moraine-mantled slopes at Sitkagi bluffs into a clean, crevassed iceberg-discharging, tidal ice front.

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## GRANBY BAY, OBSERVATORY INLET.

BY

R. G. McConnell.

### INTRODUCTION.

The objective point of this excursion is a large iron and copper sulphide deposit on Hidden creek near Granby bay, Observatory inlet, recently acquired by the Granby Consolidated Mining, Smelting and Power Company and now being opened up by them.

Observatory inlet is a deep fiord paralleling the lower portions of Portland canal and connected with it by a passage north of Pearce island. Its shore lines are more irregular than usual, and near its head it divides into two branches, the more easterly of which cuts through the granitic belt of the Coast range and terminates in the dark sedimentaries bordering it on the east. At the junction of the two arms, the inlet expands and numerous rocky islands project above the surface of the water. Granby bay is situated west of the expanded portion.

Turner and Haenke glaciers in 1906. St. Elias range in background.

34883—11½

## GEOLOGY.

Observatory inlet has its whole course in the Coast range and the rocks exposed along it consist mostly of the greyish granitoid rocks characteristic of that range. Schists outcrop along the lower portion, and at Granby bay an important area of argillites, mineralized in places, occurs as an inclusion in the granitic rocks.

The argillaceous area at Granby bay has a maximum width of nine miles (14·5 km.). It is surrounded on all sides by granitic rocks and is considered to be an undestroyed and deeply sunken portion of the old roof of the Coast Range batholith. The basin is of great depth as the rocks of the inclusion are exposed from base to summit of mountains over 5,000 feet (1,524 ,m.) in height and they must extend to a considerable depth below the present surface.

The argillites in the vicinity of Granby bay are coarsely bedded, hard, compact rocks usually altered to some extent and occasionally passing into mica and quartz mica schists. The ordinary fine grained dark variety alternates in places in thin bands with a lighter colored, coarser grained and more felspathic type made up of tufaceous material. Limestones, in small non-persistent beds, are occasionally present, and near the southern boundary of the inclusion, altered greenstones largely of pyroclastic origin are prominent.

The argillites are seldom and only over limited areas cleaved into slates. They are folded into a number of anticlines and synclines striking approximately east and west or parallel to the long axis of the area. The dips, as a rule, are regular and comparatively low, although locally the strata are greatly disturbed. No faulting on a large scale has been detected.

Dykes cutting the argillites are numerous throughout the area. Two sets, one preceding, and the other subsequent to the mineralization of the region, have been distinguished. The former are genetically connected with the enclosing granite rocks, and include a number of types ranging from quartz porphyries and pegmatites to diorites. The latter are usually lamporphyric in character.

## MINERALIZATION.

The argillaceous rocks included in the granites at Granby bay are heavily mineralized at a number of points. The most important deposits so far discovered occur on a low iron-stained hill north of Granby bay, enclosed between two branches of Hidden creek. The deposit has been explored by a tunnel driven straight into the hill for a distance of about 1,000 feet (304 m.), by numerous short drifts, by surface trenching, and by diamond drill boreholes. The mineralized area is proven by the various workings to be of great extent although it has not yet been fully defined. In shape it forms a right angle. The smaller arm, known as the first ore body, has a northeasterly strike and dips to the northwest. It has been traced from the main tunnel* in a southwesterly direction for over 600 feet (183 m.), the width averaging about 160 feet (48 m.) or, including a siliceous band which borders it on the northwest, nearly 200 feet (61 m.). The longer arm holding the second ore body has been traced in a northwesterly direction for a distance of 1,500 feet (457 m.) with an average width of about 400 feet (122 m.). The deposit has been proved by a bore-hole to a depth of 514 feet (157 m.) below the main tunnel or approximately 900 feet (274 m.) below the surface outcrops on the hill.

While only a portion of the large area described contains valuable minerals in sufficient quantities to constitute commercial ores, the original rocks are everywhere either completely altered into greenish, or less commonly brownish micaceous schists, or replaced by quartz and iron and copper sulphides. The transition from the dark, slightly altered argillites which constitute the country rocks, is usually fairly abrupt, often occurring in a few inches.

A conspicuous feature of the deposit is the presence of a zone of whitish quartz schists, practically strongly silicified argillites, traceable part way round it. This siliceous zone forms the northwestern boundary of the southwestern or smaller arm, crosses the deposit, then bending at right angles continues to the northwest as the northwestern boundary of the larger arm. It was not observed on the southwest border of the larger arm or the southeastern border of the smaller arm.

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* The examination of the deposit by the author was made in 1911. Since then much additional exploratory work has been carried on.

The rocks in the siliceous zone vary in the amount of silicification undergone. In most places they are nearly pure quartz schists, but occasionally the zone consists of alternating dark and white bands. The width of the zone ranges from 30 to 60 feet (9 to 18 m.) or more. The dip, where it skirts the smaller arm and crosses the deposit, is to the northwest, but after bending to the northwest the dip, as shown by the bore-holes, changes to the northeast. It thus forms the hanging wall of both arms. The metallic minerals present consist mainly of iron pyrite, some of it cupriferous, pyrrhotite, and subordinate quantities of chalcopyrite. A little bornite, evidently secondary, was found at one point. The principal non-metallic constituents are quartz, some calcite, a greenish micaceous schist, probably largely chloritic, some brownish micaceous schists, and occasionally some hornblende.

Pyrite is the most abundant metallic mineral present. It usually occurs in a granular condition, and in places near the surface breaks down into an iron sand. It is always associated with more or less quartz and large areas consist of pyrite grains separated by a thin siliceous matrix. It also occurs in grains and small bunches distributed through the secondary schists. Its distribution through the mineralized area is irregular, some portions containing only a small percentage, while others consist almost entirely of sulphides and quartz. The main tunnel, started some distance down the slope from the mineralized area to gain depth, passes through 380 feet (116 m.) of argillites, all somewhat altered and containing occasional grains and small bunches of pyrite, then through a pyritic zone 200 feet (61 m.) wide, becoming very siliceous towards the northwest border, then through a greenish schistose zone with some quartz and pyrite 240 feet (73 m.) wide, beyond which is a second pyritic area which continues to the end of the tunnel 120 feet (36 m). A drift to the left from a point near the end of the tunnel running about north for 300 feet (91 m) shows the continuation of the pyritic area for that distance, the breast being in granular sulphides, mostly pyrite, embedded in a siliceous matrix. A drift to the left passes through sulphides and quartz for 100 feet (30 m.) then through greenish chloritic schists, only slightly mineralized, for 120 feet (36 m.)

The comparatively barren interval separating the two pyritic areas in the tunnel is not apparent on the surface,

some of the ground overlying the lean portion being well mineralized with sulphides.

Pyrrhotite, while much less abundant than pyrite, is common throughout the greater part of the mineralized area. It occurs intermingled with the pyrite, and also forming comparatively large masses usually specked with chalcopyrite.

Chalcopyrite in grains, small aggregates of grains, and in thin layers usually accompanies the iron sulphides where the replacement is complete or nearly so, and also occurs in small quantities scattered through portions of the schistose areas. The proportion present, while variable, is always small and in certain areas seems to be absent altogether. The chalcopyrite is associated so intimately with the iron sulphides that there is little doubt that both are the products of the same period of deposition.

Bornite was found at one point, but only as a surface alteration mineral, and it does not occur so far as known as a primary mineral of the deposit.

Among the non-metallic minerals, quartz is the most prominent. A wide siliceous zone crosses and bounds portions of the mineralized area, and the large sulphide areas are all more or less siliceous. Calcite occurs occasionally but is not prominent. Portions of the area included in the mineralized zone on the accompanying map consist of greenish micaceous schists often highly siliceous. These carry significant quantities of sulphides in some places and are nearly barren in others.

The iron sulphides in the Hidden Creek mine carry very low values in the precious metals and the commercial value of the deposit depends mainly on the copper content. Chalcopyrite usually accompanies the iron sulphides, but in variable amounts. Some areas are nearly barren, while others contain sufficient quantities to constitute a low grade, and over limited areas a medium, grade copper ore.

## EXTENT AND ORIGIN OF THE ORE BODIES.

The most important body of commercial ore so far outlined in the boring operations of the Company, occurs southeast of the siliceous zone previously described as

bordering the shorter arm of the deposit on the northwest and continuing along the larger arm. The siliceous zone is fringed by a band of ore usually from 20 to 25 feet (6 to 7.6 m.) in width and already traced for a distance of nearly 1,400 feet (426 m.). A vertical bore-hole from the main tunnel apparently proves it to a depth of 514 feet (157 m.) below that level and it extends to the surface above, a variable distance, depending on the contours of the country but probably averaging about 200 feet (61 m.). The huge tonnage expected from this ore body will undoubtedly be greatly supplemented from other portions of the mineralized area. Workable areas are known to occur at a number of points, but the definition of their extent and quality awaits further exploration.

The mineralized area at the Hidden Creek mine occurs in a large predominantly argillaceous area surrounded and doubtless underlaid, although at a considerable depth, by granitoid rocks, and cut by dykes and stocks belonging to the same period of igneous intrusion. The argillites were irregularly compressed and folded at the time of the invasion, and the deposit probably occupies an area more than ordinarily crushed and fractured, although this has been masked by subsequent alteration and deposition and is not apparent. A wide, broken zone, rather than a single fissure, is conceived to have afforded the means by which heated siliceous waters carrying iron and copper sulphides in solution ascended from the underlying batholith, altering the argillites in their upward passage and replacing them with silica and sulphides as the pressure and temperature conditions became less severe.

An origin of this kind would ally the deposit genetically with the loosely defined contact metamorphic group, but the ordinary contact metamorphic minerals including the iron oxides, were not observed and are either absent altogether or are present only in very small quantities.

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# LIST OF ILLUSTRATIONS.

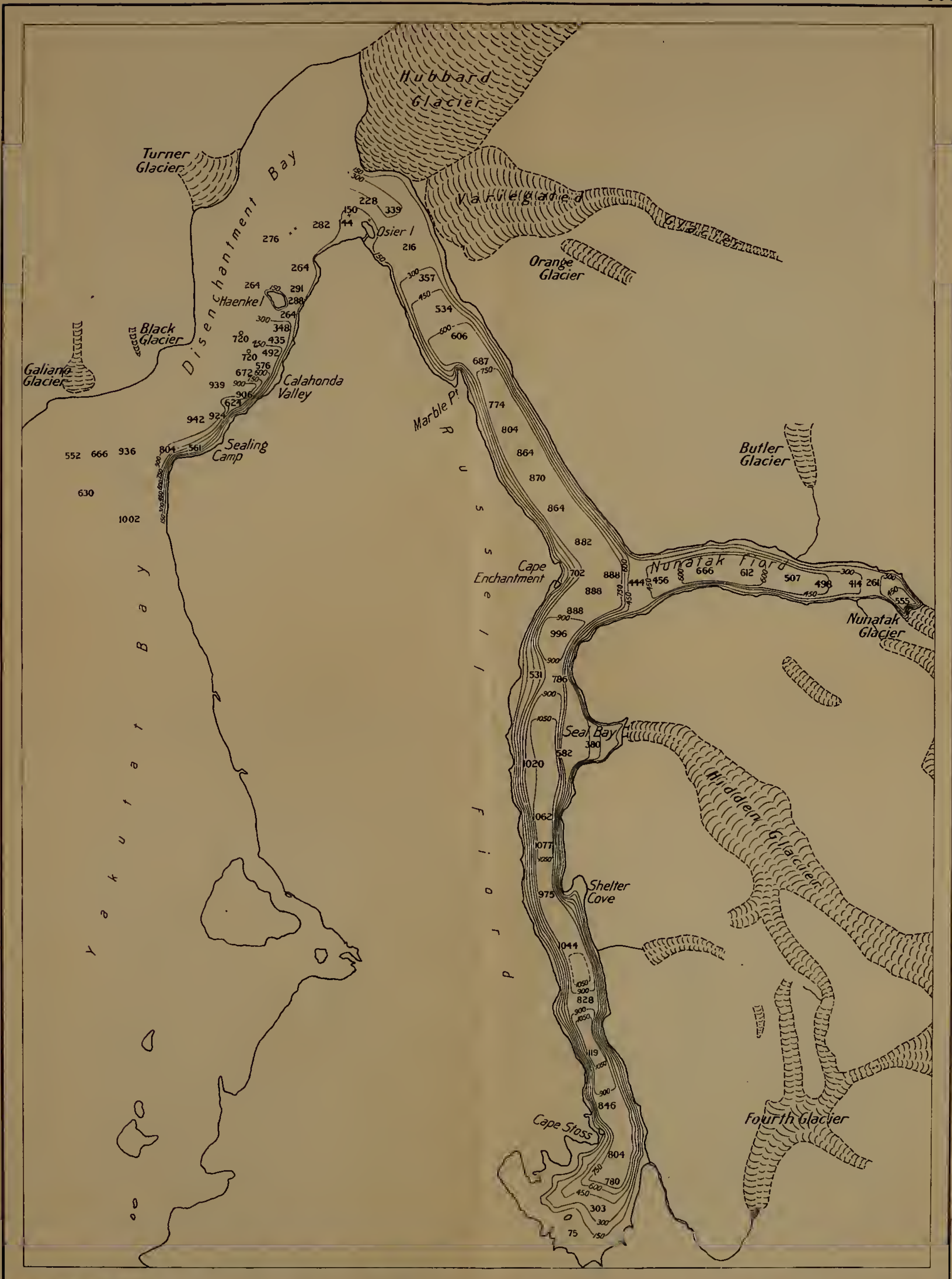
## Maps.



## Drawings and Sections.



## Photographs.



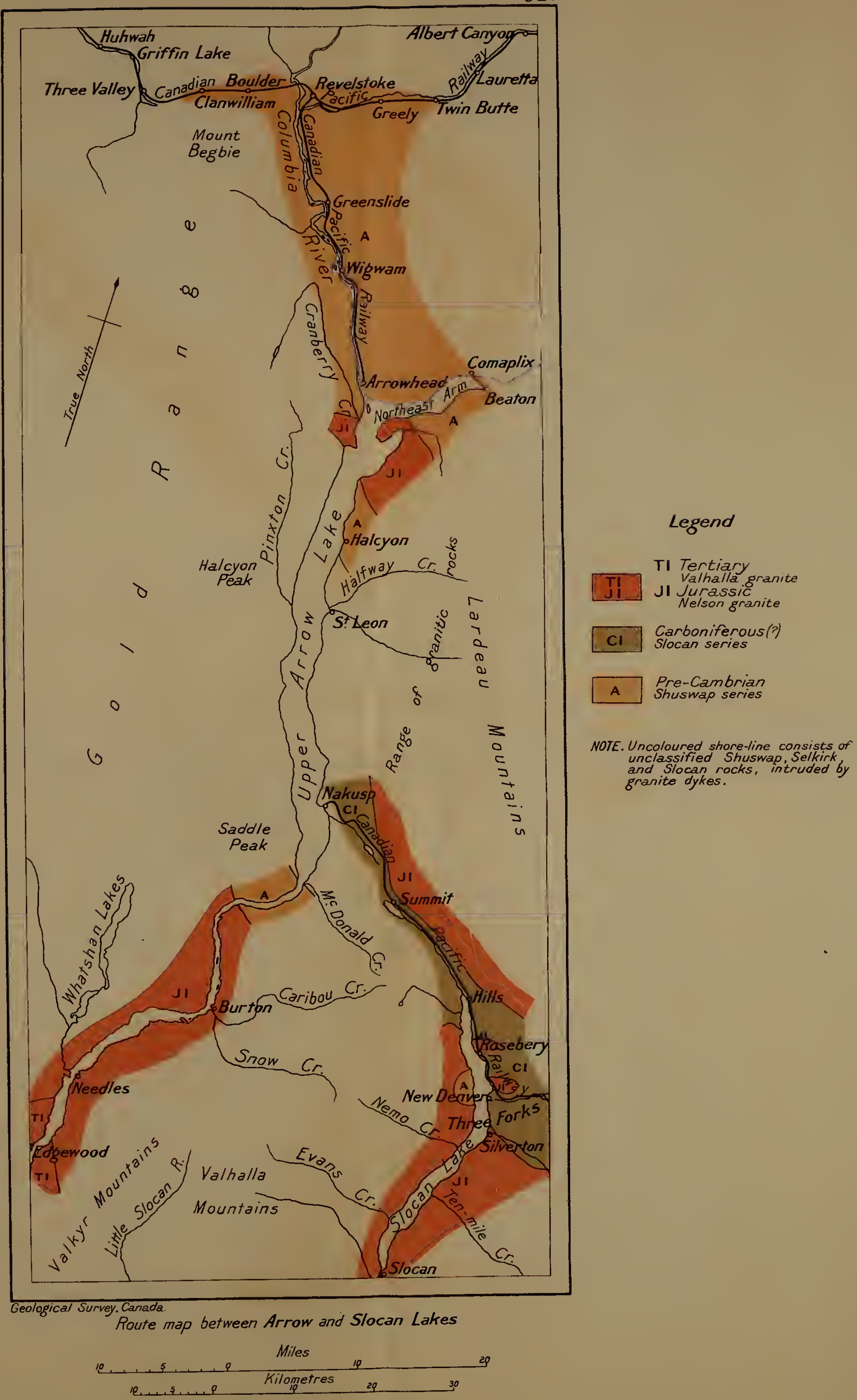

Geological Survey, Canada

Submarine Topography of Russell Fiord
(from soundings in 1910, by The National Geographic Society)

Miles

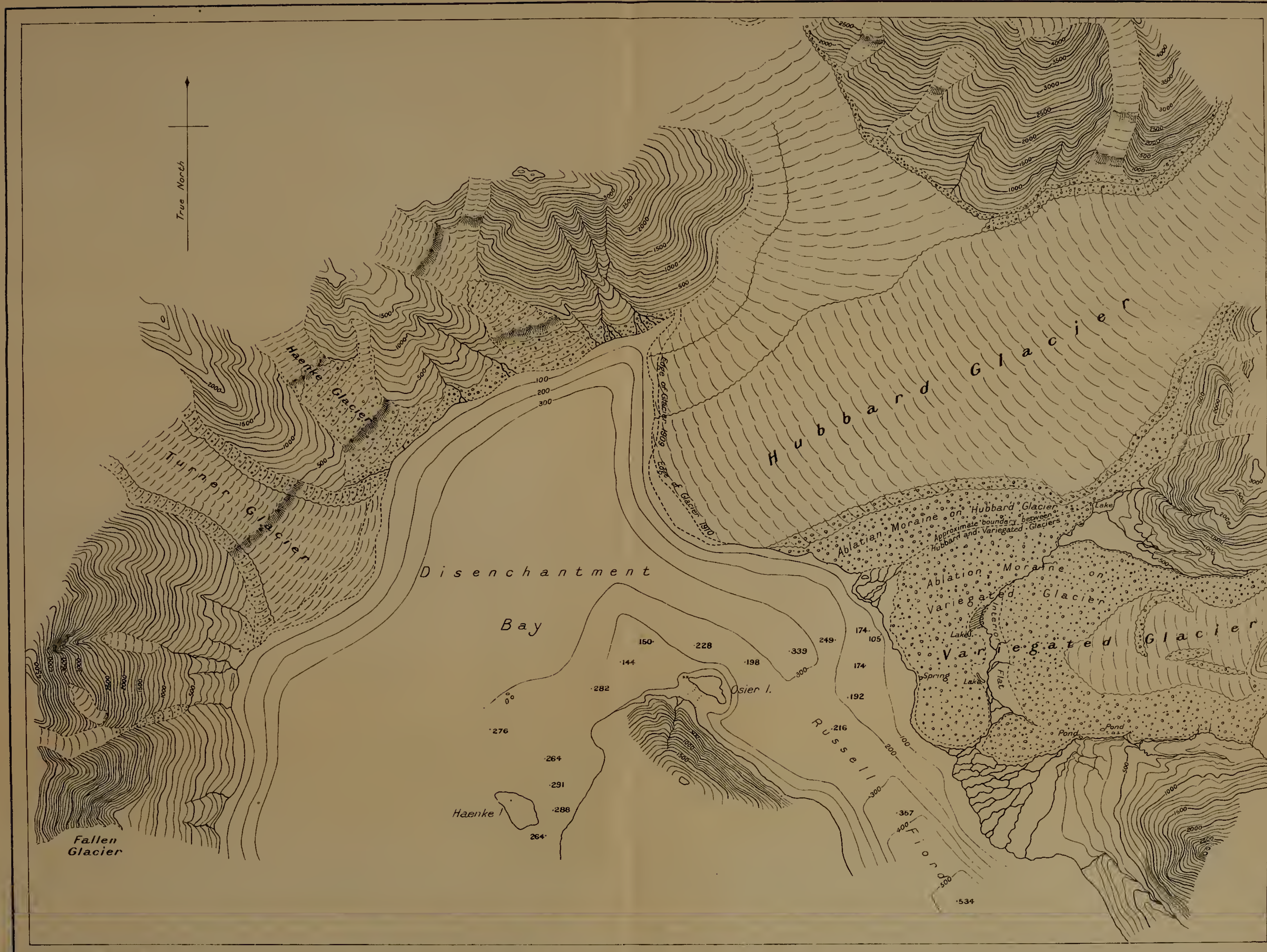
Kilometres

(Soundings shown in feet)




Geological Survey, Canada.

Route map between **Arrow** and **Slocan Lakes**




Geological Survey, Canada

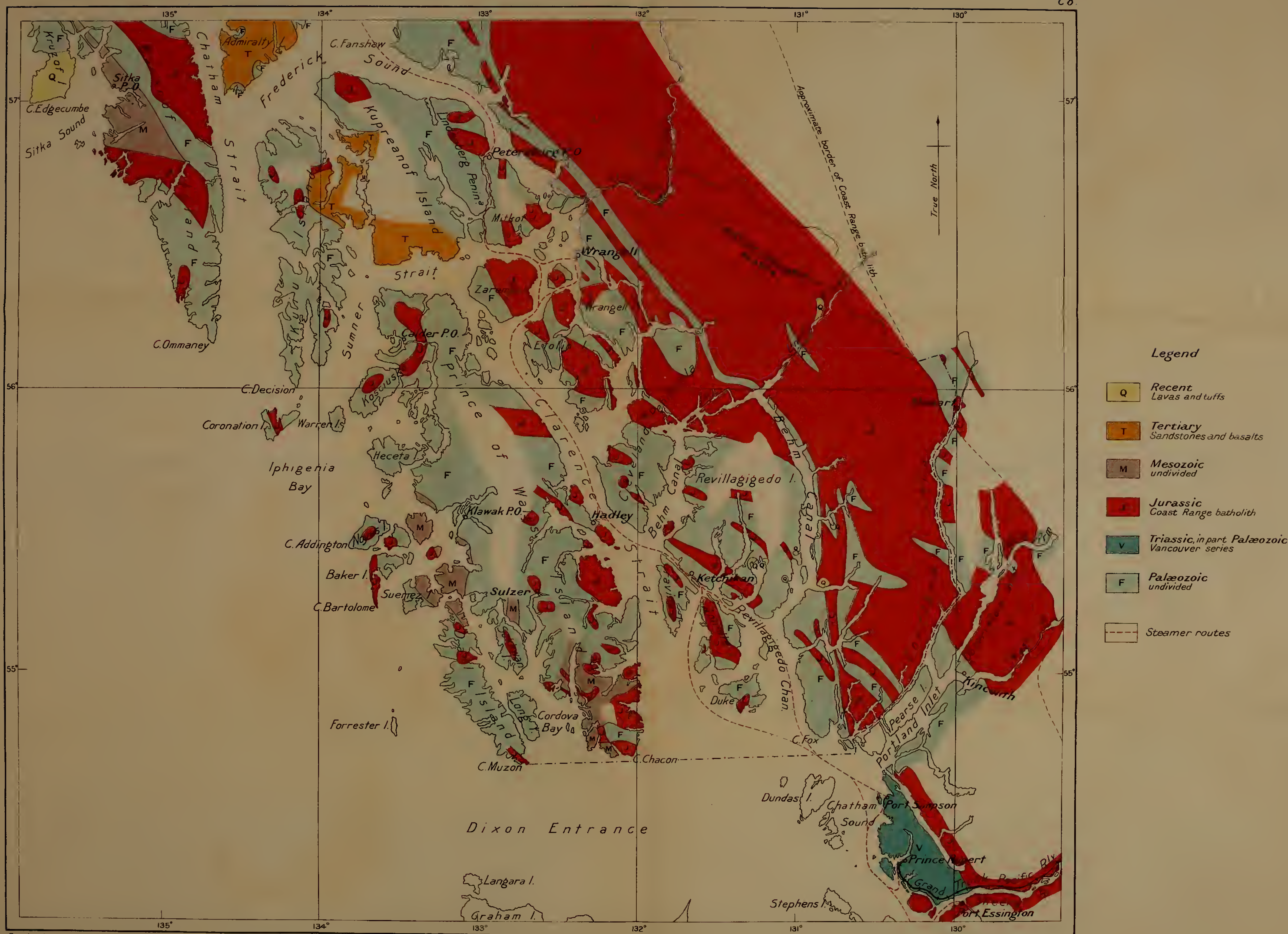
**Hubbard, Variegated and Turner Glaciers**

(Reproduced by permission of The National Geographic Society)

Miles

Kilometres

(Soundings and elevations shown in feet)




Geological Survey, Canada.

Route map between Prince Rupert and Frederick Sound

Miles
10 5 0 10 20 30 40 50 60 70 80 90 100
Kilometres
10 5 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150


Geological Survey, Canada.

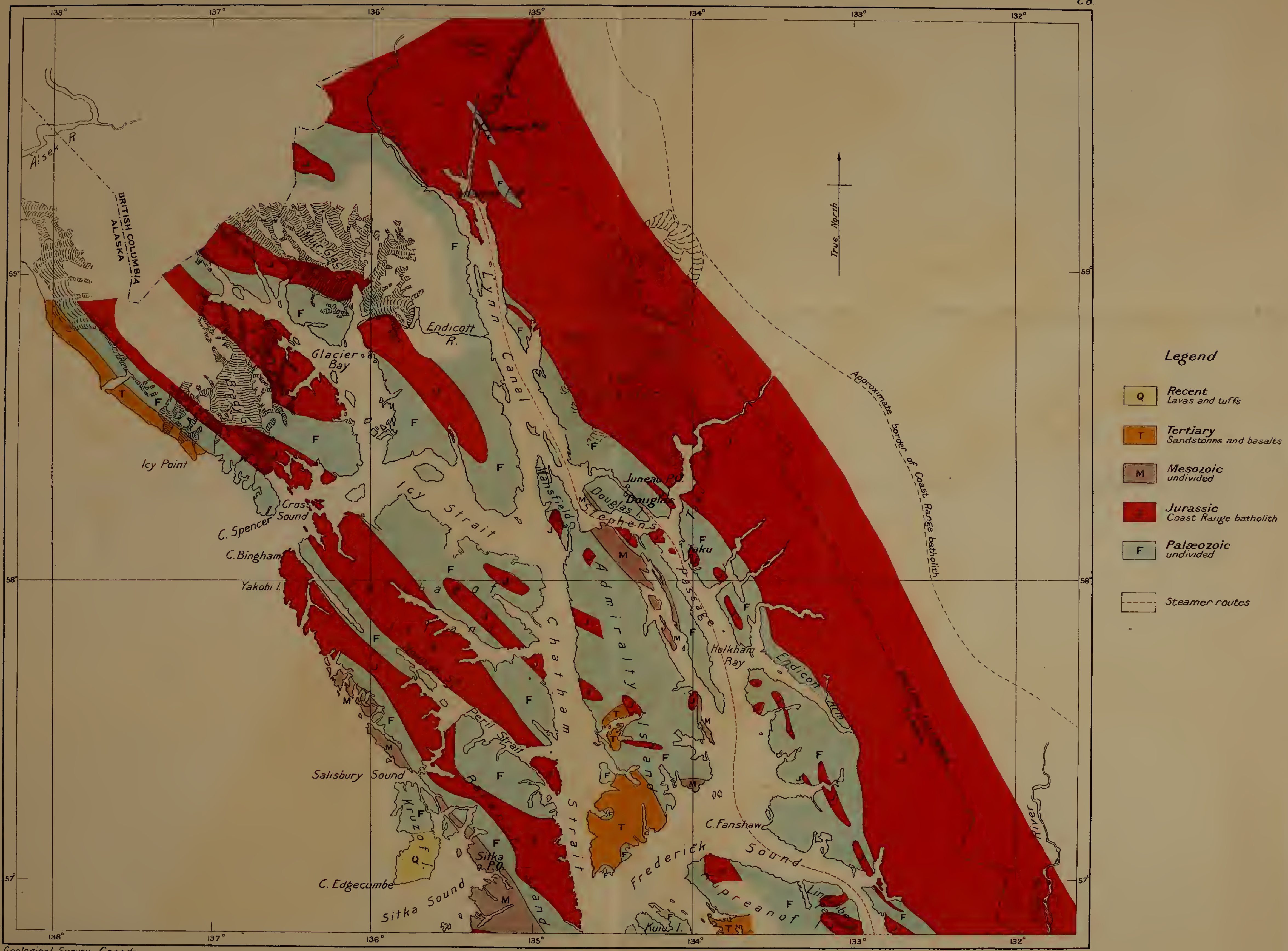
Route map between Calvert Island and Prince Rupert

Miles

10 5 0 10 20 30 40 50 60 70 80 90 100

Kilometres

10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150




Geological Survey, Canada.

Route map between Frederick Sound and Skagway

Miles 10 5 0 10 20 30 40 50 60 70 80 90 100

Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150


## Legend

- TI — *Tertiary* Eocene
- K — *Cretaceous*
- J — *Jurassic* Coast Range batholith
- Triassic
- V — *Triassic, in part, Upper Palæozoic* Vancouver series
- F — *Palæozoic* undivided
- Steamer routes

Geological Survey, Canada.

Route map between Vancouver and Calvert Island

Miles: 10 5 0 10 20 30 40 50 60 70 80 90 100

Kilometres: 10 5 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150